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AQUATIC FIELD SURVEYS AT HOLSTON ARMY AMMUNITION PLANT KINGSPORT, TENNESSEE

FINAL REPORT

J.H. SULLIVAN, JR., H.D. PUTNAM, M.A. KEIRN,
D.R. SWIFT AND B.C. PRUITT, JR.

JUNE, 1977

SUPPORTED BY
U.S. ARMY RESEARCH AND DEVELOPMENT COMMAND
WASHINGTON, D.C. 20314

J. GARETH PEARSON, PROJECT OFFICER

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WATER AND AIR RESEARCH, INC.
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The U.S. Army Medical Research and Development Command has initiated field and laboratory research for the development of environmental standards for munitions related residues. A significant portion of this effort has been directed toward field assessment at several of the munitions facilities within the United States. The purpose of these studies is to evaluate the impact of munitions waste discharge on the biotic components of freshwater ecosystems in order to establish effluent levels for maintenance of environmental quality

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in receiving waters. To meet this objective, Water and Air Research, Inc. conducted field investigations at the Holston Army Ammunition Plant during the summer of 1975.

Overall effects of munitions effluents were most clearly observed in the periphytic community and were confined to the vicinity of the waste outfalls. Marked increases in heterotrophic biomass and reduction in autotrophic populations were noted. Species composition shifts among the diatoms growing on artificial substrates suggested toxic manifestations from munitions related effluents. Effects on the periphyton were observed in water containing as little as 20 µg/l RDX. Direct relationship of RDX residues to biotic response in this system must be approached with caution. The changing chemical environment due to variable waste discharge, upstream waste inputs, and flow variability make it virtually impossible to closely quantify typical conditions at a given station. Secondly, many of the effects may be due to ancillary nitrogen and carbon discharges or to synergism between RDX and combinations of other factors. Thirdly, the environment of the Holston is one of eutrophic conditions and biological stress due to upstream discharges; thus sensitive organisms which would be expected to respond to threshold biotoxicity from RDX would not occur in the reach impacted by HAAP Area B. Much more controlled environmental conditions would be required to show direct cause and effect relationships for levels of RDX. Conservative estimates, however, would place a critical range of 20 to 100 µg/l RDX for periphyton in water containing munitions effluent.

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AQUATIC FIELD SURVEY

AT

HOLSTON ARMY AMMUNITION PLANT, KINGSPORT, TENNESSEE

FINAL REPORT

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GAINESVILLE, FLORIDA 32602

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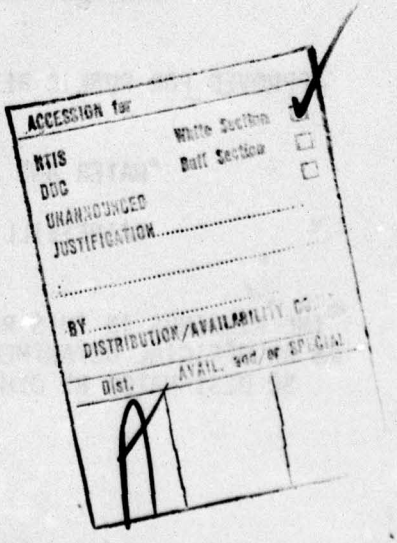

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EXECUTIVE SUMMARY

The U.S. Army Medical Research and Development Command has initiated field and laboratory research for the development of environmental standards for munitions related residues. A significant portion of this effort has been directed toward field assessment at several of the munitions facilities within the United States. The purpose of these studies is to evaluate the impact of munitions waste discharge on the biotic components of freshwater ecosystems in order to establish effluent levels for maintenance of environmental quality in receiving waters. To meet this objective, Water and Air Research, Inc. conducted field investigations at the Holston Army Ammunition Plant during the summer of 1975.

Surveys conducted in June and August considered ambient chemical and biological water quality conditions in the receiving waters of Holston Army Ammunition Plant. Munitions-related compounds from HAAP Area B (RDX, HMX, TNT, nitrogen, dissolved solids) and their effects on the periphyton and macroinvertebrate communities were evaluated.

The direct impact of munitions wastes at HAAP is difficult to assess. This is partially because flow in the Holston River is subject to wide variation due to intermittent releases from Ft. Patrick Henry Dam. Chemical and biotic species entering or indigenous to the Holston River system at Kingsport are subjected to daily flow fluctuations which may span an order of magnitude in the South Fork and in the Holston River proper. Hydrographs documenting flow conditions indicated that the capacity of the river to dilute wastes entering from HAAP vary by a factor of 12 over a 2-hour period.

The study section of the river carries substantial industrial discharges from HAAP Area A and other Kingsport industries as well as domestic sewage from the city of Kingsport. Previous studies have indicated that these discharges create critically low dissolved oxygen concentrations (1 mg/l) in the impact area as well as elevated temperatures (up to 11.5^{0} C above ambient). Also, the wastes from HAAP Area B are dispersed among three outfalls. The two upstream outfalls discharge RDX, organic solvents, and some nitrogenous wastes. The third discharge consists of large quantities of nitrate nitrogen and some RDX. This latter discharge enters the river downstream at Arnott Branch.

The third facet complicating data interpretation is wastes from HAAP Area B enter the Holston in a mixing reach of waters from the North and South Forks. These waters have widely divergent chemical characteristics. Marked cross-sectional differences were observed in dissolved oxygen concentration, temperature, and conductivity farther down river than the confluence of Arnott Branch. This information suggests that the waters of the North and South Forks behave as distinct, contiguous streams occupying the same stream bed from the point of confluence to some point downstream of the plant site. Results of dye tracer tests bear this out and suggest that the impact of HAAP waste from Area B would be limited to the northern one-half of the stream bed. Less than uniform dispersal of wastes occurs downstream for several miles. As a result, biotic components inhabiting opposite sides of the river within that reach are subjected to widely dissimilar water quality.

The major water quality impacts of HAAP Area B include the addition of up to 700 µg/l RDX residues to the waters along the north bank. These are detectable in concentrations ranging from <5 to 70 µg/l nearly one mile downstream. Flow conditions held the plume to the north bank. Peak river concentrations were found at levels 29-150 µg/l during June and up to 700 µg/l immediately below the two upstream outfalls in August. The only south bank station showing residues was Station 19 immediately across from Arnott Branch. The flow of this creek probably pushed effluent across the river at this point. No HMX or TNT residues were detectable in the river waters. In contrast to the distribution of residues in the waters, no RDX was detectable in the sediments at >0.2 mg/kg. Trinitrotoluene residues up to 4.2 mg/kg were found in the sediments along the north bank and at Station 12 downstream. In general, concentrations increased with distance downstream from the upper outfalls to Arnott Branch.

Enrichment of the north bank waters with nitrogen and carbon from HAAP effluent, also, is reflected in sediment concentrations below the outfalls. Sediments on the north bank of the river exhibited elevated organic nitrogen and chemical oxygen demand values which progressively increased downstream of the production line effluents. All three outfalls contribute a variable, but significant, carbonaceous load to the river, which resulted in slight carbon increases in the water along the north bank. Total organic carbon in the effluents ranged 8-330 mg C/l in June, 7-93 mg C/l in August. This resulted in average carbon concentrations of 8 to 10 mg C/l with an upper value of nearly 18 mg C/l in the river downstream of the effluents. The added carbon would aggravate the oxygen stress existing in the Holston by increasing oxygen demand.

The major plant nutrient discharge from HAAP Area B is nitrogen. Downstream increases in nitrate concentrations occurred along the north bank below Arnott Branch. The nitrate nitrogen concentration at that point ranged to 4.5 mg N/l during the August survey. Reduced nitrogen (TKN) levels in the Holston are high due to discharges into the South Fork upstream of HAAP Area B. During the June survey, TKN values were highest along the south bank. Data from the August 1975 survey and a 1969 EPA survey suggest a major reduced nitrogen input into the Holston from HAAP Area B, especially at Arnott Branch.

Measurement of dissolved oxygen and temperature showed that low D.O. may stress biologic communities in the survey reach, especially during times of low flow in the South Fork. Dissolved oxygen concentrations measured during the day ranged from 1.5 mg/l to 11.2 mg/l during the two survey periods. Critically low oxygen concentrations may occur frequently in the impact reach.

The biological communities of the Holston River in the survey reach are under several kinds of ecological stress. Water quality and quantity fluctuate drastically over short time periods. Only those taxa which are tolerant to variations in flow, periodic low dissolved oxygen levels, as well as intermittent high levels of nitrogen and organic materials would be expected to inhabit this reach. Since the natural populations would be stress tolerant, this complicated the analysis of the

subtle effects of low level munitions compound releases. This factor limited the usefulness of macroinvertebrates, normally important indicators of water quality, in clearly defining the minimum levels of RDX having an environmental effect. Both colonization of artificial substrates and examinations of the river sediments were employed to assess the impact of HAAP Area B waste on this component of the community. The two methods provide information relative to two environments, the water (artificial substrate) and the substrate (sediment samples).

Oligochaetes were the dominant group of macroinvertebrates collected in the study area. These were found at all stations and accounted for 76 percent of the organisms collected from both natural and artificial substrates. Common among those genera identified were Limnodrilus hoffmeisteri, a tubificid; and Nais pseudobtus, Paranais, Pristina schmeideri and Stylaria -- all Naididae. These organisms are considered tolerant of nutrient and organic pollution. Oligochaetes and Hirudinea (leeches), also found at all stations in the survey, are known to be tolerant as a group to low oxygen concentrations and periods of anaerobiasis.

The plumonate snail, Physa, occurred in tremendous numbers covering large sections of exposed river bank. Extremely large populations were found in the weed beds along the south bank. Planarians (Turbellaria) were abundant, especially on the artificial substrate samples. They were present at all stations except directly below the second outfall ditch.

Chironomids, mainly Chironomus attenuatus, were abundant. The dominant species is a freshwater form tolerant to widely ranging pH, turbidity, and organic enrichment.

All of the common taxa, along with the more uncommon forms, are generally considered tolerant to low oxygen levels and organic pollution. This dominance at all stations indicates eutrophic conditions in the Holston River. Population distribution patterns showed depression in density of organisms and reduced numbers of taxa immediately below HAAP effluent outfalls. Further downstream at Station 12, there was evidence of recovery. Upstream of the effluents, macroinvertebrates were more diverse on artificial substrates ($\bar{H}$ = 2.2) than immediately below the outfalls (0.9 - 1.4). Diversity of benthic macroinvertebrates changed little from the June-July to the August-September survey.

The water quality data show that macroinvertebrates may be affected not only by RDX, but also by associated carbon and nitrogen compounds. Maximum impact in the river sediments was observed immediately below the two upper production line outfalls. The impact observed below these outfalls was limited to a short reach extending 100 to 200 yards downstream along the north bank. Whole river effects were not discernible.

Seven species of filamentous algae and 114 species of diatom representing 31 genera were recorded as periphyton from artificial substrates placed in the study reach. A selected number of natural substrates was also analyzed for diatom community structure. Data from these latter substrates showed little discernible effect of HAAP wastes

on the diatom populations studied. In general, the periphytic flora of impact and reference stations suggests that the Holston River supports a relatively large population of pollution resistant filamentous algae, characteristic of nutrient enriched waters. Diatom species assemblages also suggested an enriched trophic state. Effects of munitions effluents were noted in the periphytic component in the vicinity of the waste outfalls. These were manifested by reduction in algal populations and shifts in the diatom species associations. Gross changes occurred immediately below the effluent discharges among the filamentous organisms which predominated on the artificial substrates. Chlorophyll a concentrations and organic biomass, quantitated from incubated glass slides, also suggest a toxic impact from HAAP Area B effluents. This impact was manifested by elevated levels of heterotrophic biomass and concommitant reduction in chlorophyll content and algal flora of the impact areas.

Large populations of the pollutant tolerant filamentous chlorophyte, Stigeoclonium tenue, dominated the algal flora at both the upstream stations and the stations in the impact area. However, in the immediate vicinity of the production line effluents, the periphyton community was heavily dominated by heterotrophs, predominantly Sphaerotilis natans. Along with this form, sewage tolerant protozoan species, Carchesium polypedium and Epistylis sp., formed major components of the populations attached to the glass slides. The upstream population and the shift in the impact zone suggest that organic carbon and nitrogen enrichment from upstream create conditions favoring an algal flora tolerant of extremely eutrophic conditions. Additional inputs of organic chemicals, organic nitrogen and nitrates stimulate lush growths of nuisance sewage bacteria and associated heterotrophs which predominate directly below the production lines' discharges.

Populations of Stigeoclonium were greatly reduced downstream from HAAP, possibly indicating recovery from the effects of pollution of the South Fork waters above HAAP Area B and the effects of HAAP wastes per se. At this station the predominant primary producers were filamentous blue-green algae, Oscillatoria submembrancea, Schizothrix arenaria, and S. calicola. These organisms also are indicators of nutrient rich waters.

The impact related community structure changes among the filamentous periphytic flora were supported by chlorophyll a and biomass data. The presence of carbon enrichments from organic solvents, in combination with nitrogen discharges from the two upstream production lines, stimulated the production of a heterotrophic, nonchlorophyllous community along the north bank immediately below these outfalls.

Changes in the diatom population structure showed sensitivity to discharges from HAAP Area B. The trophic level status of the common species recorded indicated an eutrophic diatom assemblage, characteristic of nutrient rich waters which are stressed by elevated carbon. Common to dominant species were: Achnanthes minutissima, Cocconeis placentula v. euglypta, Gomphonema intricatum v. pimula, G. angustatum v. producta, G. parvulum, Cymbella sinuata, Navicula cincta, Rhoicosphenia curvata, and Stephanodiscus sp.

In general, populations of diatoms were higher along the south bank and upstream, in contrast to the north bank area of impact. Major changes in diatom species dominance correlated with elevated levels of RDX, NO_3-N, TKN and TOC being discharged from the HAAP effluent lines. Reproduction of dominant species was suppressed at impact stations, while more resistant species took over dominance of this component. Species diversity indices ($\bar{H}$) for the diatom population were relatively low throughout the study. The mean values ranged from 1.14 to 2.53. Overall mean was 1.88. This index was relatively unaffected, however, by impact of HAAP Area B. Changes in the population structure, therefore, were in terms of species replacements. One diatom assemblage, comprised of three species: Achnanthes minutissima, Cocconeis placentula v. euglypta, and Gomphonema intricatum v. pimula, was sensitive to waste impact. This assemblage was replaced at the impact stations by another Achnanthes species.

Overall effects of munitions effluents were most clearly observed in the periphytic community and were confined to the vicinity of the waste outfalls. Marked increases in heterotrophic biomass and reduction in autotrophic populations were noted. Species composition shifts among the diatoms growing on artificial substrates suggested toxic manifestations from munitions related effluents. Effects on the periphyton were observed in water containing as little as 20 µg/l RDX. Direct relationship of RDX residues to biotic response in this system must be approached with caution. The changing chemical environment due to variable waste discharge, upstream waste inputs, and flow variability make it virtually impossible to closely quantify typical conditions at a given station. Secondly, many of the effects may be due to ancillary nitrogen and carbon discharges or to synergism between RDX and combinations of other factors. Thirdly, the environment of the Holston is one of eutrophic conditions and biological stress due to upstream discharges; thus sensitive organisms which would be expected to respond to threshold biotoxicity from RDX would not occur in the reach impacted by HAAP Area B. Much more controlled environmental conditions would be required to show direct cause and effect relationships for levels of RDX. Conservative estimates, however, would place a critical range of 20 to 100 µg/l RDX for periphyton in water containing munitions effluent.

INTRODUCTION

The U.S. Army Medical Research and Development Command has supported field and laboratory research for the development of environmental standards for munitions related residues. A significant portion of this effort has been directed toward field assessments at the various munitions facilities within the United States. These studies have been for the purpose of evaluating impact on the various biotic compartments in freshwater systems in order to establish effluent levels in receiving waters consistent with the maintenance of environmental quality.

To meet these objectives, Water and Air Research, Inc. conducted field investigations at Holston Army Ammunition Plant during the summer of 1975.

The Holston Army Ammunition Plant is located near Kingsport, Tennessee on the Holston River (Figure 1). The complex has been divided into two sections: Area A occupies 112 acres approximately four miles below the Ft. Patrick Henry Dam on the north bank of the river; Area B totals 5,913 acres of land along about four miles of the Holston River. The production plant is in Area B; RDX, HMX, TNT and other constituents involved in munitions manufacture are produced here and their wastes discharged into the Holston.

Augmenting wastes from munitions compounds, this section of the river carries substantial industrial discharges from ASG Industries, Inc., J. P. Stevens and Company, Inc., Mead Papers, Penn-Dixie Cement Corporation, and the Tennessee Eastman Company. Consequently, the environmental effects of munitions wastes from the Holston Army Ammunition Plant are difficult to assess. River stage in the Holston is subject to wide variation. Superimposed on munitions impact is influence from the above cited industrial wastes. The area of impact falls in a mixing reach of waters of widely divergent chemical characteristics from the North and South Forks of the Holston River. Also the wastes from HAAP enter from outfalls along the north banks. These discharge RDX, organic solvents and some nitrogen compounds. Downstream large quantities of nitrate-nitrogen and some RDX enter from Arnott Branch.

The purpose of this investigation was to characterize the munitions related waste from HAAP and to assess the impact of these wastes on the ecology of the receiving water bodies. Therefore, as a part of the investigation, a dye study utilizing fluorescent Rhodamine WT was made with the Turner Designs Model 10 field fluorometer to assess the mixing and distribution of the effluent through the riverine system (see Water Quality).

Twenty sampling station locations (Figures 2 and 3) were selected throughout the study area. These were located in the North and South Fork upstream of the munitions production lines; continued through the area of influence to a point well down river at the boundary of the reservation. Surveys were completed in June and August of 1975.

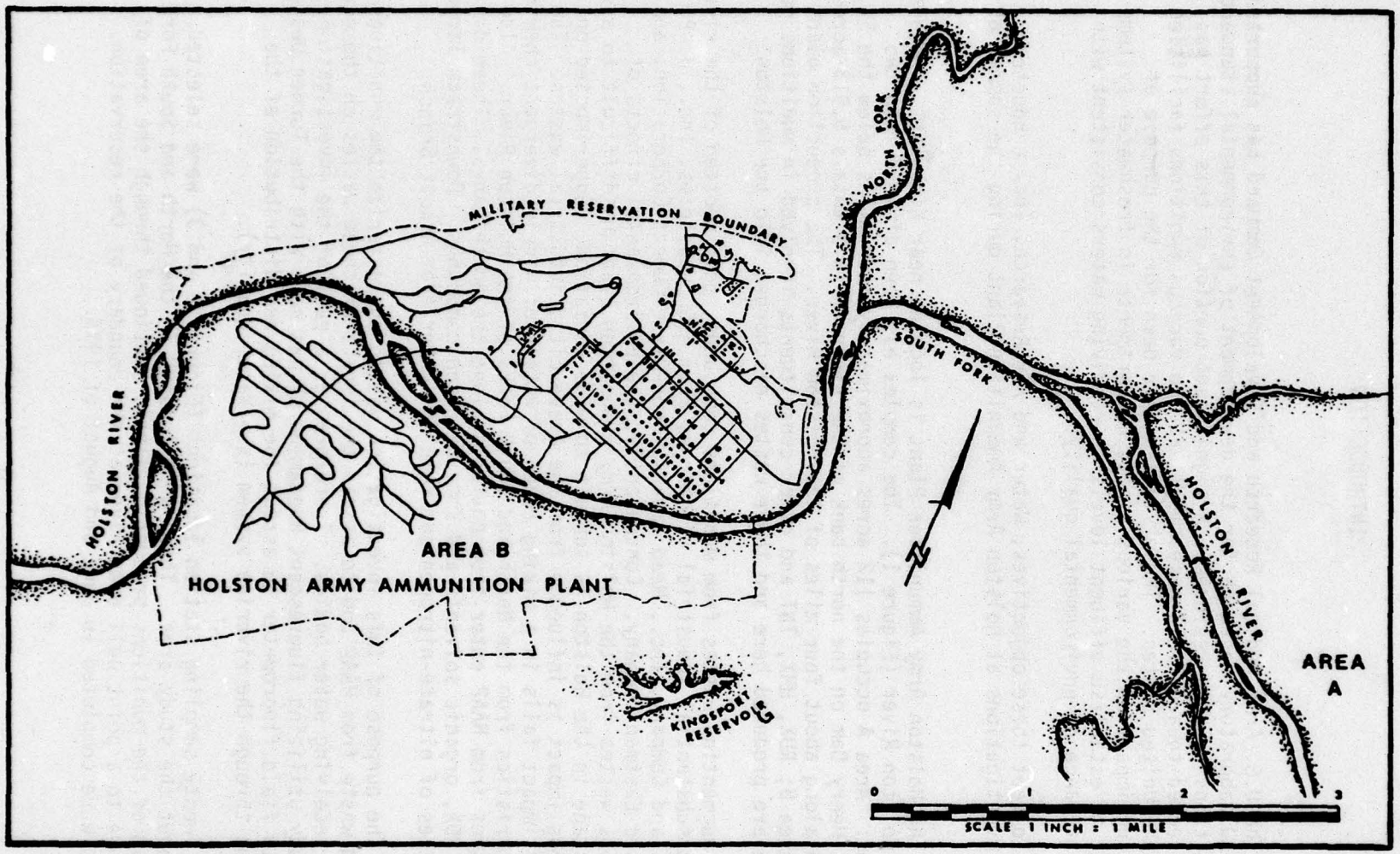

FIGURE 1. VICINITY MAP OF HAAP STUDY AREA.

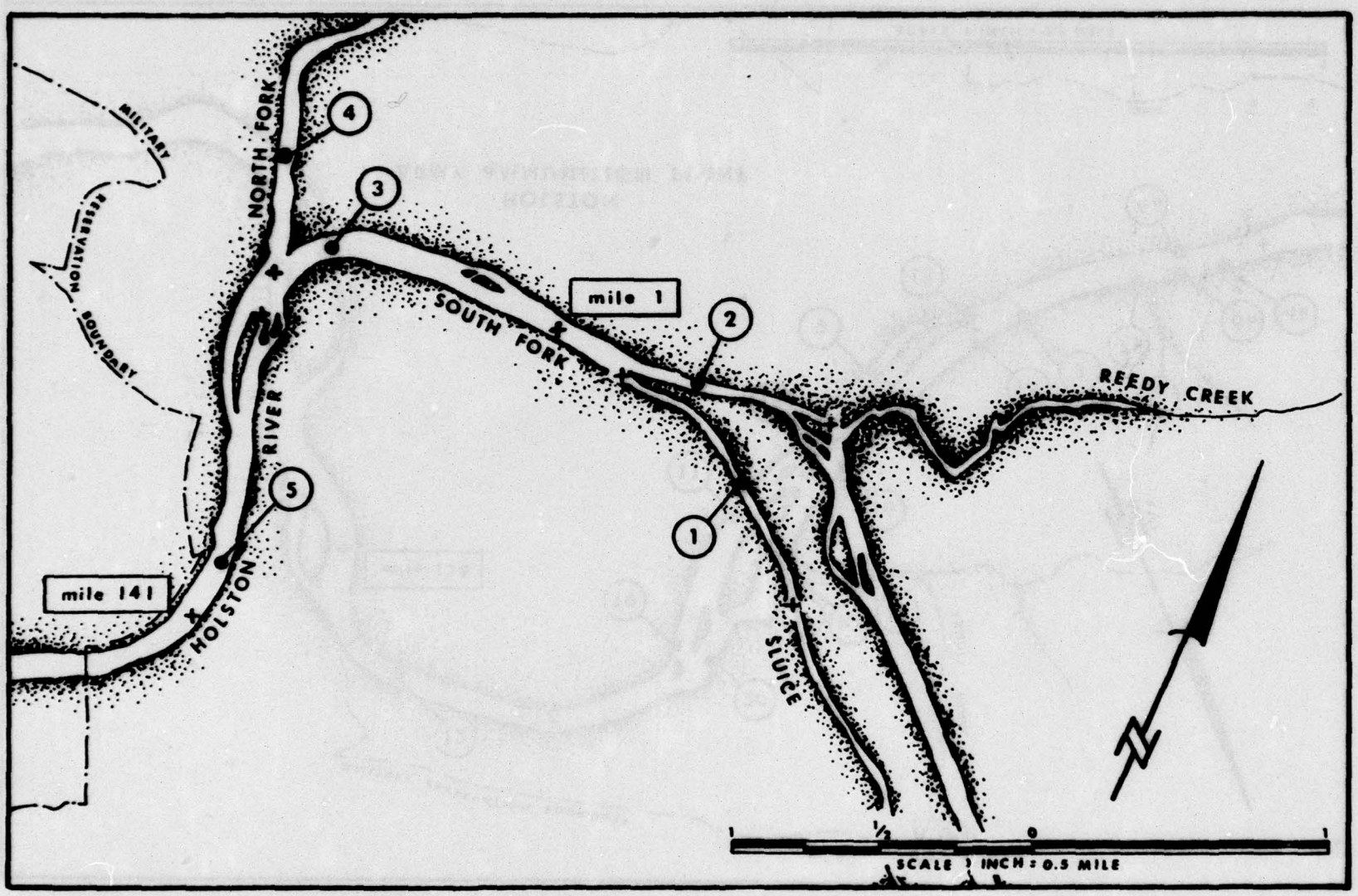

FIGURE 2. UPSTREAM SAMPLING STATIONS IN THE HOLSTON RIVER (HAAP STUDY).

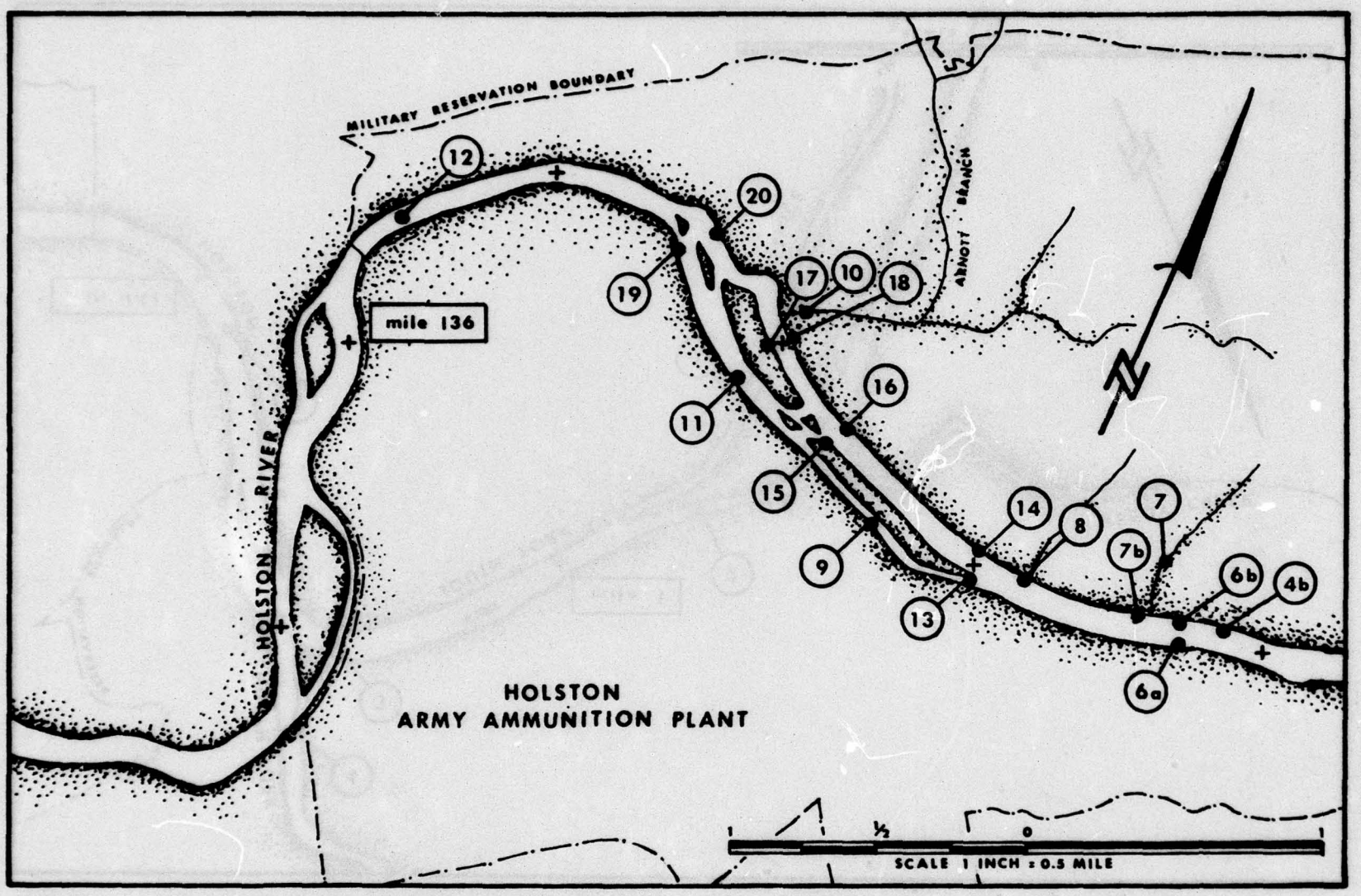

FIGURE 3. DOWNSTREAM SAMPLING STATIONS IN THE HOLSTON RIVER (HAAP STUDY).

The combined June and August surveys, considering as they did effluent discharge, distribution, mixing characteristics, changes and/or alterations in the chemical, biological, or sediment characteristics of the Holston River, provided a portion of the data base for the recommendation of effluent guidelines for munitions wastes into receiving bodies.

WATER QUALITY

Introduction

The Holston River, located in southwest Virginia and northeast Tennessee, is formed by the confluence of the North Fork and the South Fork at Kingsport, Tennessee. The June and August environmental survey was conducted in this general area of the river, but was mainly concentrated in the reach immediately downstream of the confluence which is impacted by the Holston Army Ammunition Plant Area B.

During the study a characterization of the water quality and river sediments was achieved by considering the river waste loadings; trends in the river conditions obtained from previous studies; and data collected by WAR, Inc. With this information the biotic variation in the impacted reach was related to munitions-specific discharges from HAAP.

Impacts of Munitions Related Discharges on Water Quality

A considerable data base is being developed through contract research by the Army Medical Research and Development Command to characterize the environmental effects of munitions discharges. Major impact effects from a water quality standpoint are increased color; "red water," resulting from photochemical action on nitrobodies; large increases in dissolved solids, mostly chlorides and sulfates; nitrogen enrichment; as well as munitions release. Failure of waste neutralization processes can result in significant pH changes. Effects on sediments include nitrogen and organic enrichment, buildup of salts, and accumulation of munitions compounds and their degradation products. Table 1 summarizes the major water quality impact compounds cited in recent studies on munitions discharges.

Existing reports related to the impact of HAAP discharges include Evaluation of the Effects of Holston Army Ammunition Plant Wastes on the Biota of the Holston River, Tennessee by WAPORA, Inc. (1975) and the EPA (1972). The latter report with emphasis on Kingsport, Tennessee discussed nitrogen, phosphorus, and biochemical oxygen demand loading from the Holston Army Ammunition Plant.

The WAPORA study characterized water quality and biological conditions and concluded that the major effluents of the explosive production line may be contributing to the low level of dissolved oxygen; and increases in total solids, total dissolved solids, total Kjeldahl nitrogen, and chemical oxygen demand in the river.

Methods

Field Analysis and Sample Collection. During two 5-day survey periods, June 2-6, and August 4-8, samples and field measurements were taken at twenty sites, arrayed between river miles 136 and 144. The predominant effort was concentrated along the reach which receives HAAP-B discharges. The samples

TABLE 1

SUMMARY OF WATER QUALITY IMPACTS OF
MUNITIONS MANUFACTURING WASTEWATER DISCHARGES

Munitions Plant	Contractor and Date	Munitions Manufactured	Receiving Water Body	Munitions Related Impacts on Water Quality
Badger Baraboo, WS	Battelle 1974	Nitrocellulose	Gruebers Bay Wisconsin River	TDS, $S0_4$, NO_2-N, NO_3-N, Cl, Nitrocellulose
Holston Kingsport, TN	WAPORA 1975	RDX/HMX	Holston River	TKN Solids, Hg, COD
Iowa Burlington, IA	ENCOTEC 1975	TNT	Small Creeks	TDS, Nitrogen Compounds, Cl, SO_4, TNT, Sediment Enrichment
Joliet Joliet, IL	Battelle 1974	TNT	Grant Creek near confluence with Kankakee and Des Plains Rivers	TKN, SO_4, NO_2-N, NO_3-N, Al, Fe, COD, TOC
Lake City Ks. City, MO	Battelle 1974	Nitrocellulose	Little Blue River	TDS, Cl, Cu, Sb, SO_4, Nitrocellulose
Longhorn Marshall, TX	WAR 1975	TNT	Stabilization lagoons	TDS, NO_3-N, NO_2-N, TKN, Cl, Hardness, Mg, TNT, Color
Louisiana Shreveport, LA	WAR 1975	TNT	Stabilization lagoons	TDS, NO_3-N, NO_2-N, TKN, Cl, Hardness, Mg, TNT, Color
Milan Milan, TN	WAPORA 1975	Loading TNT & other materials	Obion River	TNT, NO_3-N
Radford Radford, VA	WAPORA 1975	TNT	New River	TNT, TDS, TOC, SO_4, NO_2-N, NO_3-N, TKN, Color
Volunteer Chattanooga, TN	WAPORA 1975	TNT	Chickamauga Lake (Waconda Bay)	NO_2-N, NO_3-N, SO_4, Color, TOC, Solids

were preserved in accordance with EPA (1974) methods and shipped to WAR, Inc. in Gainesville, Florida for processing.

Field parameters - dissolved oxygen (DO), temperature, pH, and specific conductance - were monitored at various times throughout the day in order to assess the oxygen resources of the river. Dissolved oxygen was measured with a YSI model 51B DO meter. Specific conductance and temperature were measured with a YSI Model 33 Salinity-Conductivity-Temperature Meter. Measurement of pH was made with a Photovolt Model 126A portable battery-operated pH meter.

Laboratory Analyses. Samples were collected as described and shipped refrigerated to WAR, Inc. The water quality parameters monitored included the following:

Major Ions

Total Alkalinity
Chloride
Total Hardness
Sulfate
Total Dissolved Solids (TDS)

Suspended Materials

Suspended Solids (SS)
Total Solids

Oxygen Demand

Chemical Oxygen Demand (COD)
Total Organic Carbon (TOC)

Trace Metals

Cadmium (Cd)
Copper (Cu)
Chromium, Hexavalent (Cr^{+6})
Iron (Fe)
Lead (Pb)
Mercury (Hg)
Nickel (Ni)
Zinc (Zn)

Plant Nutrients

Ammonia Nitrogen (NH_3-N)
Total Kjeldahl Nitrogen (TKN)
Nitrite Nitrogen (NO_2-N)
Nitrate Nitrogen (NO_3-N)
Total Phosphorus (Total-P)

Munitions Compounds

2,4-Dinitrotoluene (2,4-DNT)
2,6-Dinitrotoluene (2,6-DNT)
α-Trinitrotoluene (TNT)
Cyclotrimethylenetrinitramine (RDX)
Cyclotetramethylenetetranitramine (HMX)

The sediments were characterized by analyzing the following parameters:

Nutrients	Trace Metals
Chemical Oxygen Demand (COD)	Cadmium (Cd)
Total Kjeldahl Nitrogen (TKN)	Copper (Cu)
Nitrate Nitrogen (NO_3-N)	Chromium, Hexavalent (Cr^{+6})
Nitrite Nitrogen (NO_2-N)	Iron (Fe)
Total Phosphorus (Total P)	Lead (Pb)
Total Solids	Manganese (Mn)
Total Volatile Solids	Mercury (Hg)
	Nickel (Ni)
	Zinc (Zn)

Munitions Compounds

2,4-Dinitrotoluene (2,4-DNT)
2,6-Dinitrotoluene (2,6-DNT)
α-Trinitrotoluene (TNT)
Cyclotrimethylenetrinitramine (RDX)
Cyclotetramethylenetetranitramine (HMX)

The methods employed for collecting, preserving and analyzing the routine water quality parameters followed accepted Standard Methods (APHA, 1971) or EPA (1974) procedures. Chemistry Laboratory Manual Bottom Sediments (EPA, 1969) was the source of the routine methods utilized for collection, preservation, and analysis of the sediment samples. Where existing methods, particularly for trace metals and munitions were insufficient to provide the desired levels of detection, alternate analytical procedures were employed after accuracy and precision had been verified. Details on analytical procedures are presented in Appendix A-1.

Waste Loading in the Upper Holston River

The EPA (Region IV) had been concerned for some years with water quality especially low oxygen concentrations and nutrient loading of the Holston River from the confluence of the North and South Forks to the Cherokee Reservoir, 40 miles downstream. The agency has made two waste source and stream surveys; the first in July, 1969 (EPA, 1972) and the second in November and December, 1972 (EPA, 1973a and 1973b). These sought to determine the quality and quantities of wastes discharged into the Holston River in order to establish NPDES permitting limits, to evaluate control measures, and to ascertain the changes in the water quality in the Holston River in terms of specific pollutants, i.e. nitrogen, phosphorus, organic loading, and organic chemicals.

The 1969 study demonstrated that the waste dischargers at Kingsport, Tennessee; principally:

Tennessee Eastman Corporation (TEC)
Holston Army Ammunition Plant
  Areas A and B (HAAP-A, HAAP-B)
Mead Papers (MEAD)
Kingsport Sewage Treatment Plant (KSTP)

seriously affected water quality in the South Fork and Holston River. At the time of the 1969 survey, 137,500 pounds per day BOD and 19,500 pounds per day TKN -- the latter discharged primarily by TEC (83%) and HAAP (16%) -- were creating conditions violating Tennessee Stream Standards (see below) for USGS rivermile 131.5 to 142.

Minimum Dissolved Oxygen (D.O.$\geq$ 3.0 mg/l)
Maximum Total Dissolved Solids, 500 mg/l;
pH 6.5 - 8.5;
Maximum Temperature, 30.5°C
Maximum Temperature rise, 3°C. (EPA, 1972).

The TKN discharge was calculated to be equivalent to 84,000 pounds per day of nitrogenous oxygen demand (NOD).

Figure 4 shows the downstream oxygen sag curve from the Kingsport reach. In addition, temperature increases of 11.5°C were observed from TEC and HAAP-A cooling water discharges. A further 1.3°C rise from HAAP-B resulted below Arnott Branch. Water from the North Fork contained little oxygen demand but affected water quality by contributing elevated chlorides and hardness from Olin Corporation, Saltville, Virginia. In addition, TEC as well as HAAP-A and HAAP-B contributed significant phosphorus to the system.

A modeling effort based on this survey indicated that nitrogenous oxygen demand (NOD) contributed 30 percent of the total loading and that reduction of carbonaceous demand was not sufficient to upgrade water quality. The EPA concluded that waste reduction to no more than 14,000 lb/day BOD and 1,950 lb/day TKN would be required to maintain stream standards. The BOD and TKN loads discharged during the 1972 study -- 111,500 lb/day BOD, 11,600 lb/day TKN -- still greatly exceeded the limits. Table 2 taken from EPA 1973a, tabulates the waste discharges found during the two surveys. In addition to the generated oxygen demand, the table shows the heavy NH_3-N and NO_3-N loading which supports a large standing crop of aquatic plants. These growths contribute to oxygen fluctuation (Figure 5) which result in night time DO levels as low as 1 mg/l because of respiratory demands.

Acute bioassays of the wastes from the various outfalls of TEC and HAAP-A and HAAP-B suggested toxicity in these effluents to fathead minnows. Based on the 1972 waste flow from HAAP-B and these bioassay results, a minimum river flow of 2,600 cfs would be required to prevent toxic conditions downstream, assuming no residual toxicity from HAAP-A or TEC.

NPDES requirements for 1977 are tabulated in Table 3; the new permit allows lower discharges than 1972. Implementation of waste treatment facilities for process wastes, containment of spillage, and separate treatment of cooling water streams are required to meet these goals. In addition to meeting the effluent standards as tabulated, bioassays to assure that toxicity of HAAP-B wastes are less than or equal to receiving water toxicity are required as a part of the permitting requirements.

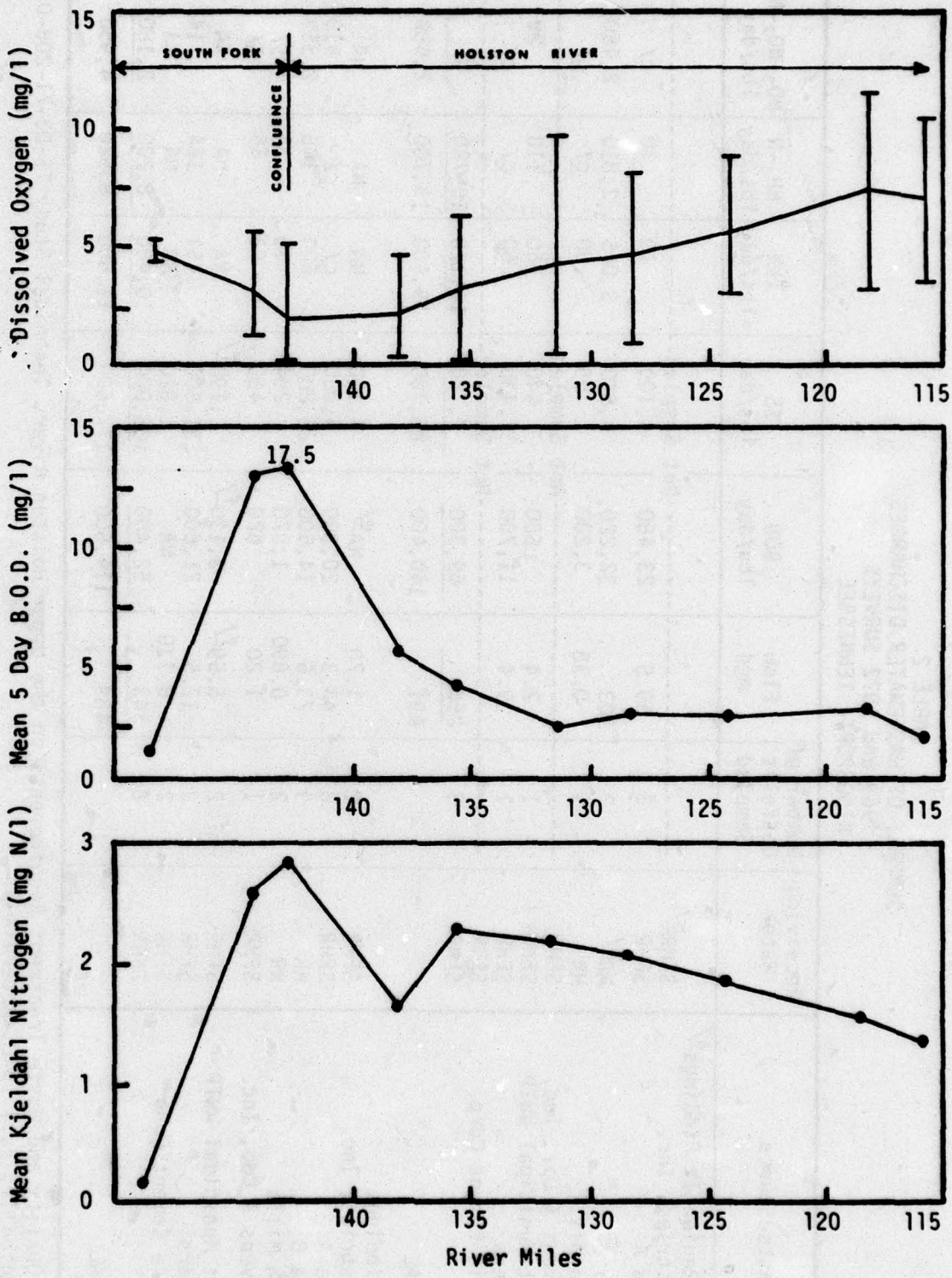

FIGURE 4. WATER QUALITY UPPER HOLSTON RIVER, JULY 25 - 28, 1969, FROM EPA, 1972.

TABLE 2
SUMMARY OF WASTEWATER DISCHARGES
1969 and 1972 SURVEYS
KINGSPORT, TENNESSEE

Waste Source	Receiving Water	Number of Outfalls Sampled	Flow mgd	BOD lbs/day	SS lbs/day	TKN lbs/day	NH_3-N lbs/day	NO_3+NO_2-N lbs/day
1969 FWQA Region IV Findings[a/]								
ASG Industries, Inc.	SFHR[b/]	----------	----------	----------	Not Sampled	----------	----------	----------
HAAP-Area A	SFHR	3	59.5	23,480	4,100	10	10	c/
Area B	HR[d/]	7	103	32,220	4,840	3,045	2,810	2,460
Holliston Mills	HR	1	0.38	3,200	89	30	c/	c/
J.P. Stevens & Co., Inc.	SFHR	----------	----------	----------	Not Sampled	----------	----------	----------
Kingsport Municipal WWTP	SFHR	1	2.4	500	440	160	110	20
Mead Papers	SFHR	1	9.4	11,700	11,430	60	c/	c/
Penn-Dixie Cement Corp.	SFHR	----------	----------	----------	Not Sampled	----------	----------	----------
TEC	SFHR	3	256	69,300	7,780	16,120	10,780	c/
TOTAL			431	140,400	28,700	19,400	13,700	2,480
1972 EPA Findings								
ASG Industries, Inc.	SFHR	2	1.70	NA[e/]	4,100	NA	NA	NA
HAAP-Area A	SFHR	8	43.3	20,300	4,060	c/	c/	419
Area B	HR	9	73.6	14,600	26,800	600	106	2,352
Holliston Mills	HR	2	0.890	1,970	294	39	14	c/
J.P. Stevens & Co., Inc.	SFHR	1	1.20	620	460	93	36	c/
Kingsport Municipal WWTP	SFHR	2	6.59[f/]	3,130[f/]	2,190[f/]	NA	NA	NA
Mead Papers	SFHR	2	17.5	21,600	31,500	451	164	14
Penn-Dixie Cement Corp.	SFHR	2	0.770	NA	1,810	NA	NA	NA
TEC	SFHR	8	343	52,400	106,000	10,400	8,200	2,180
TOTAL			489	114,600	177,600	11,600	8,520	4,950

a/ Water Quality and Waste Treatment Requirements on the Upper Holston River, Technical Study TS-03-71-208-07, EPA Region IV, July 1972, Appendix B.
b/ This stands for South Fork of the Holston River.
c/ This load was not significantly greater than that of raw water.
d/ This stands for Holston River.
e/ NA stands for Not Analyzed.
f/ This value is average yearly summary of plant records.

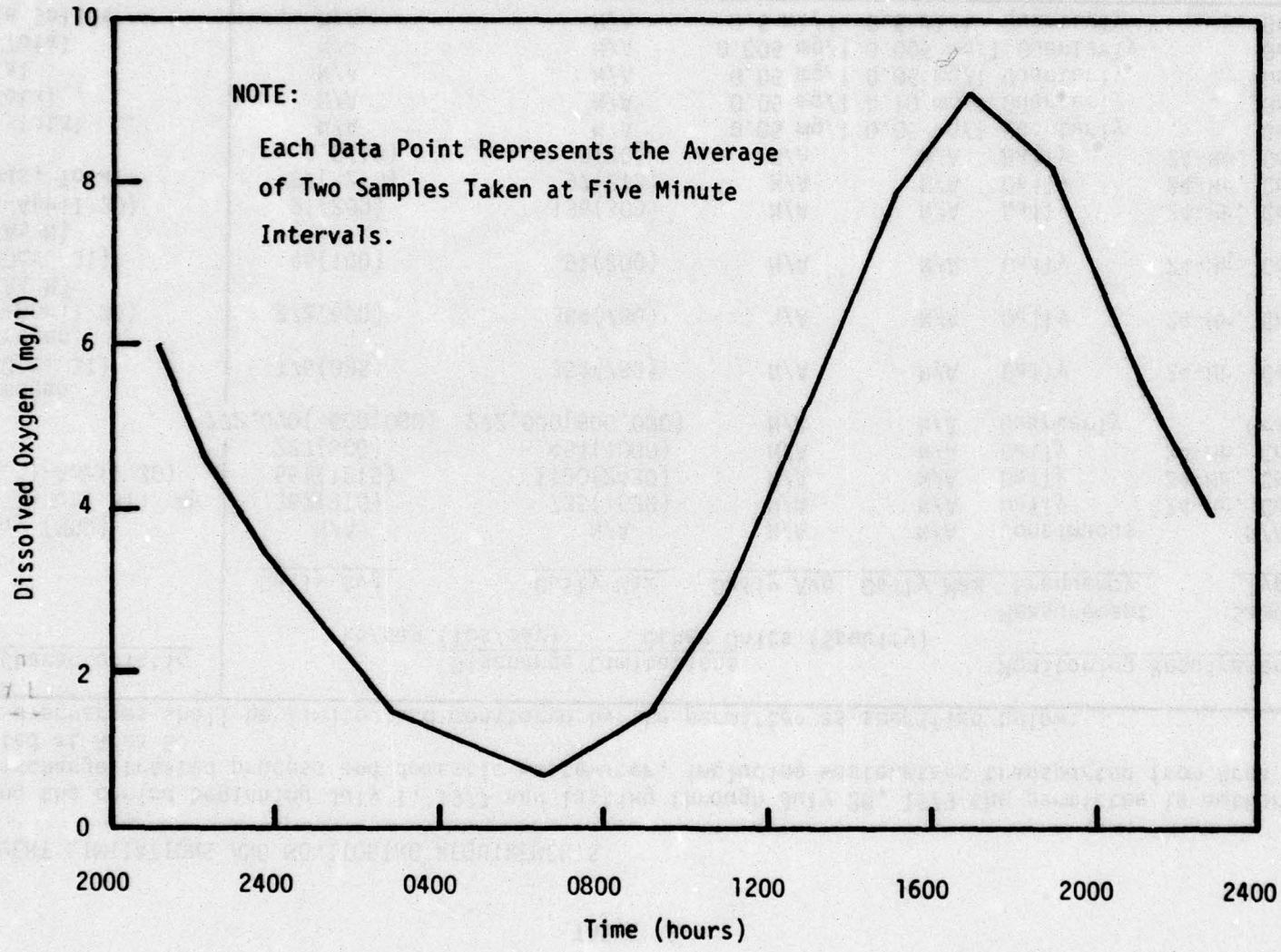

FIGURE 5. DISSOLVED OXYGEN VARIATION R.M. 131.5, HOLSTON RIVER, JULY 26 - 27, 1969 FROM EPA, 1972

TABLE 3

EFFLUENT LIMITATIONS AND MONITORING REQUIREMENTS

During the period beginning July 1, 1977 and lasting through July 28, 1979 the permittee is authorized to discharge treated process and domestic wastewater, including wastewaters transported from Area A and treated at Area B.
Such discharges shall be limited and monitored by the permittee as specified below:

Effluent Characteristic	Discharge Limitations kg/day (lbs/day)		Other Units (Specify)		Monitoring Requirements	
	Daily Avg	Daily Max	Daily Avg	Daily Max	Measurement Frequency	Sample Type
Flow-m^3/Day (MGD)	N/A	N/A	N/A	N/A	Continuous	N/A
BOD_5 (May 1-Oct. 31)	367(810)	735(1620)	N/A	N/A	Daily	24-Hr. Composite
BOD_5 (Nov. 1-April 30)	551(1215)	1100(2430)	N/A	N/A	Daily	24-Hr. Composite
T.S.S.	227(500)	454(1000)	N/A	N/A	Daily	24-Hr. Composite
T.D.S.	<272,000(<600,000)	272,000(600,000)	N/A	N/A	Quarterly	Grab
Total Nitrogen (May 1-Oct. 31)	175(385)	354(780)	N/A	N/A	Daily	24-Hr. Composite
Total Nitrogen (Nov. 1-April 30)	272(600)	354(780)	N/A	N/A	Daily	24-Hr. Composite
Ammonia (As N) (May 1-Oct. 31)	45(100)	91(200)	N/A	N/A	Daily	24-Hr. Composite
Ammonia (As N) (Nov. 1-April 30)	91(200)	136(300)	N/A	N/A	Daily	24-Hr. Composite
Phosphorous, Total	<97(<213)	97(213)	N/A	N/A	Daily	24-Hr. Composite
Phenols	4.5(10)	9(20)	N/A	N/A	Daily	24-Hr. Composite
Chromium, Total	N/A	N/A	0.05 mg/l	0.05 mg/l	Quarterly	Grab
Copper, Total	N/A	N/A	0.05 mg/l	0.10 mg/l	Quarterly	Grab
Lead, Total	N/A	N/A	0.05 mg/l	0.05 mg/l	Quarterly	Grab
Mercury, Total	N/A	N/A	0.005 mg/l	0.005 mg/l	Quarterly	Grab
Settleable Solids	N/A	N/A	0.5 ml/l	0.5 ml/l	Quarterly	Grab

Characterization of Water Quality

The effect of munitions compounds and associated wastes discharges from HAAP-B on water quality in the upper Holston River is difficult to assess. This is because flow in the Holston River is subject to wide variation due to intermittant releases from Ft. Patrick Henry Dam. Superimposed on the flow variability are the waste discharges at Kingsport which reduce the quality of South Fork water. The area of impact also is in a mixing reach of waters of widely divergent chemical characteristics, i.e. the North and South Forks of the Holston. Finally wastes from HAAP enter the river from three outfalls along the north bank. Two upstream outfalls from production lines 2 - 8 discharge munitions residues, organic solvents, and some nitrogen compounds. The third, from the nitric acid area, discharges large quantities of nitrogen and some munitions residues. According to U.S. Army Environmental Hygiene Agency (USAEHA, 1972) the three wastes streams discharge at the following rates:

Station 7	Production Lines 6, 7 & 8	48 MGD Approximately
Station 8	Production Lines 2, 3, 4 & 5	11 MGD Approximately 10 MGD Cooling Water
Station 10	Arnott Branch	Natural Flow 2.5 MGD Cooling Water 46 MGD Process Wastewater 15 MGD

During the 1975 survey, waste flows were substantially less than these values.

Water quality data for selected major ions, plant nutrients, trace metals, and munitions, as well as associated field measurements, are tabulated in Appendices A-2 - A-6. Appendix A-7 tabulates selected sediment analyses.

Field Data Presentation. Field measurements of dissolved oxygen, temperature, conductivity, and pH were made during the June and August surveys. The results are given in Appendix A-2.

Previous studies (EPA, 1972, 1973a, 1973b) showed the Holston River in the vicinity and downstream of HAAP to be under dissolved oxygen and temperature stress. The oxygen demand was due to BOD (55 percent), NOD (30 percent), and benthic deposits (15 percent). Some 91 percent of the BOD and 99 percent of the NOD resulted from discharges by Tennessee Eastman Corporation and HAAP. In July, 1969, dissolved oxygen concentrations in the Holston River just downstream of Arnott Branch (River Mile 137.9) dropped to as low as 0.2 mg/l in the early morning hours. Temperatures rose as high as 31.5°C. Dissolved oxygen in the North Fork varied diurnally from 6.2 to 11.4 mg/l. During the June and August, 1975 survey, the temperature and dissolved oxygen minimum and maximum were 15.0°C - 31.0 °C and 1.5 mg/l - 11.2 mg/l, respectively. Since no dissolved oxygen measurements were made at night, values of 1 mg/l or below probably occurred in the pre-dawn hours. Low dissolved oxygen in August occurred in the South Fork during periods of minimum or no discharge of water at Ft. Patrick Henry Dam.

When water release from the dam creates high flow conditions in the South Fork and dissolved oxygen in the North and South Forks is greater than 7 mg/l, oxygen sag is observed downstream of the confluence in the study reach. At low flow and lower D.O. (5 mg/l) in the South Fork, no D.O. sag occurs, viz oxygen concentrations increase downstream via reaeration. This phenomenon is likely due to the effect of fluctuating river flow, stage, or reaeration.

Apparently, as water is released from the dam, the increased velocity is more than offset by increased depth causing reaeration to diminish. Under these conditions reaeration would be less at higher flows. At low dissolved oxygen, although the deficit is greater, the reaeration constant is higher. In addition, low river stage increases riffle areas. This means that the driving force for reaeration is greater and reoxygenation over-balances oxygen demand.

Mixing of North and South Fork waters was not complete until River Mile 137. Marked cross sectional differences in dissolved oxygen, temperature, and conductivity were observed at all sampling locations as far downriver as Stations 19 and 20 (approximate River Mile 137.5). Dissolved oxygen concentrations were higher in the waters from the North Fork that were adjacent to the HAAP manufacturing areas and received the HAAP effluents. Minimum observed dissolved oxygen values in these waters were 6.9 mg/l in June and 4.4 mg/l in August. This emphasizes the adverse water quality impact of Kingsport on South Fork waters.

During the survey, pH ranged between 7.0 - 8.2 which are values normally anticipated for natural waters.

Conductivity was generally higher in the North Fork as shown in the following table. These results are consistent with historical data.

	June	August
	(μmho/cm)	
North Fork (Station 4)	250 - 630	260 - 870
South Fork (Station 3)	139 - 220	180 - 270
Holston River (Station 12)	230 - 300	200 - 335

Transport - Dispersion Considerations. Chemical and biotic species entering or indigenous to the Holston River system at Kingsport are subjected to daily flow fluctuations which may span an order of magnitude in the main channels of the South Fork and Holston Rivers and two orders of magnitude in the auxiliary channel of the South Fork. This is a consequence of the widely varying turbine discharge at Ft. Patrick Henry Dam. Hourly discharge at this TVA facility ranged from 0 to a maximum of 9,900 cfs during both the June and August surveys. Low flow in the South Fork during the two study periods was not less than approximately 540 cfs (10 cfs in the auxiliary channel, 530 cfs in the main channel), and peak flow did not exceed 10,600 cfs (1,700 cfs in the auxiliary channel, 8,900 cfs in the main channel).

Hydrographs documenting flow conditions in the South Fork, North Fork, and Holston River during the June and August surveys are presented

as Figures 6 and 7. These are based upon provisional USGS data and illustrate the extreme variability and frequency of flow conditions encountered in this riverine system. Flow data reported for the North Fork are estimated from the stage records at Gate City, Virginia, and ranged from 770 to 2,090 cfs in the June study and from 176 to 1,880 cfs in the August study.

It is evident from the hydrographs that the potential capacity of the Holston River to dilute wastes entering from HAAP may vary by a factor of 12 within 2 hours. Time of travel of the turbine discharge pulse from point of origin to the gauging station on the South Fork was approximately 2 hours, indicating the approach velocity of the discharge crest to be 3 fps.

Aerial photographs of the Holston River system at Kingsport (TVA dated February 4, 1973) show slow mixing of the North and South Fork Rivers downstream of their confluence. Against the more transparent water of the South Fork, the turbid water of the North Fork is discernible as an opaque ribbon as far downstream as River Mile 136. Conductivity profiles recorded during the June and August field surveys (Figures 8 and 9) adjacent to the north and south banks of the Holston River show that mixing extended from the point of confluence to at least River Mile 138 during extremes of turbine discharge, a distance of 4.2 miles. This information suggests that the waters of the North and South Fork behave as distinct, contiguous streams occupying the same streambed from the point of confluence to some point downstream of the HAAP-B plant site. As a result, biotic constituents inhabiting opposite sides of the river within that reach are subjected to quite dissimilar water quality. In addition, the inhibited dispersion of waste effluents from the plant attendant to this phenomenon might intensify impact in a zone adjacent to the north bank (which adjoins the plant site), while diminishing or precluding impact in the remaining portions of the stream bordering the south bank.

Dye tracer tests were conducted during the June survey to characterize further the dispersion of wastes entering the Holston River from three plant outfall zones: Station 7, Station 8, and Arnott Branch. During each test, the red fluorescent dye, Rhodamine WT, was fed as a 34 parts per thousand (V/V) solution continuously into the outfall ditch or tributary by a positive displacement chemical feed pump (a Lapp Hydracone Simplex Pump) at a nominal rate of 400 ml concentrated dye per minute. This rate was calculated to result approximately in a 0.5 ppb concentration of Rhodamine WT if the dye were completely dispersed over the river cross-section at a maximum anticipated flow of 8,000 cfs.

Dye profiles were recorded at selected intervals in the reach downstream of Rhodamine injection by traversing the river in a boat equipped with a Turner Design Model 10 Fluorometer/Rustrak Recorder system, which monitored the dye levels in river water circulated continuously through the fluorometer flow cell by a 12 volt Jabsco pump and garden-hose sampler. The fluorometer, after adjustment for background fluorescence, was sensitive to 0.1 ppb Rhodamine concentration. Dye profiling commenced after approximate steady state conditions were judged to be present in the river (determined by the visual appearance of the dye plume and occasional dye sampling -- in no case before 60 minutes elapsed time from dye injection). Profiles were established in upstream-to-downstream order.

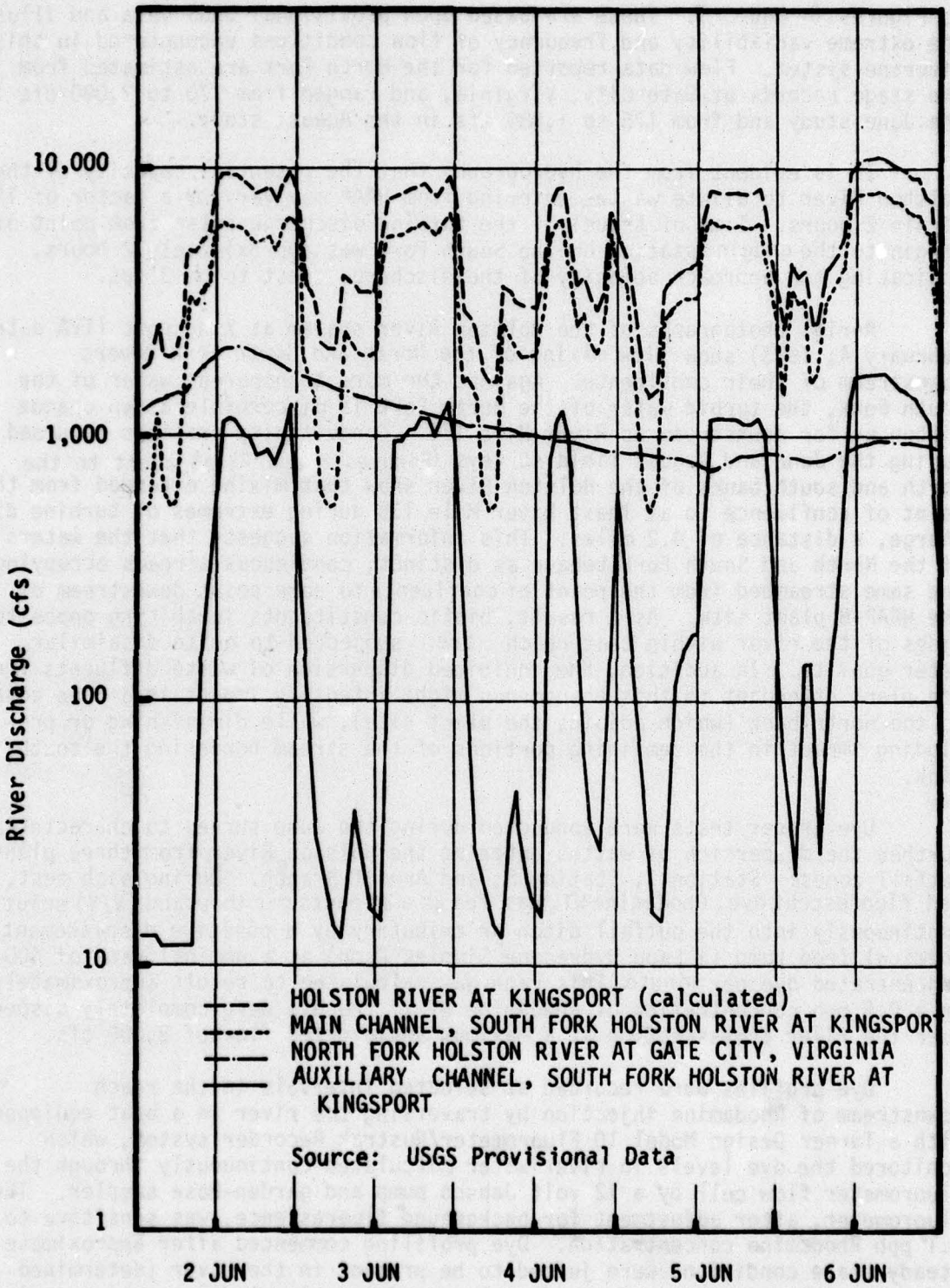

FIGURE 6. STREAMFLOW DATA FOR THE HOLSTON RIVER AND TRIBUTARIES AT KINGSPORT. JUNE, 1975 SAMPLING TRIP.

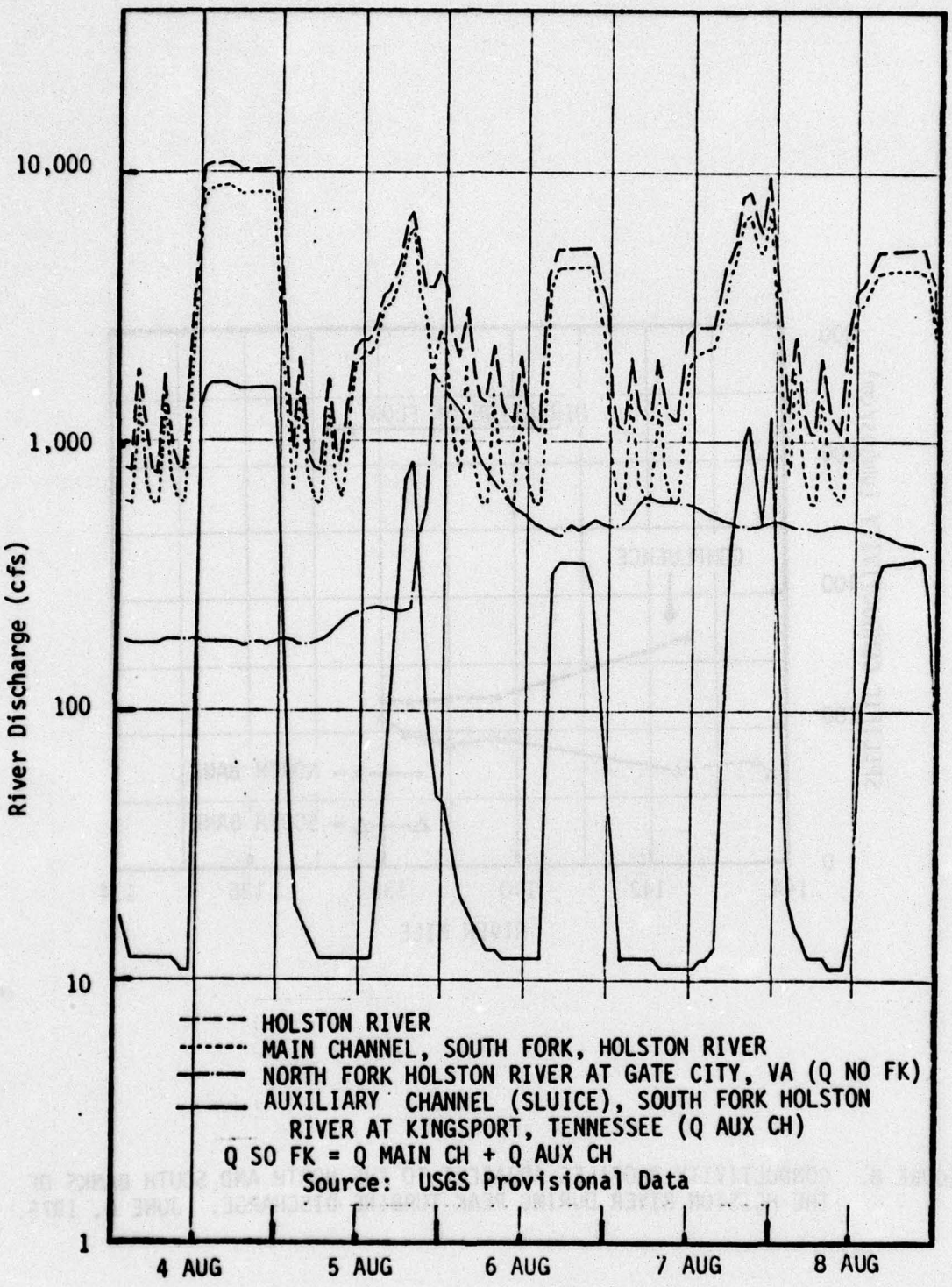

FIGURE 7. STREAMFLOW DATA FOR THE HOLSTON RIVER AND TRIBUTARIES AT KINGSPORT. AUGUST, 1975 SAMPLING TRIP.

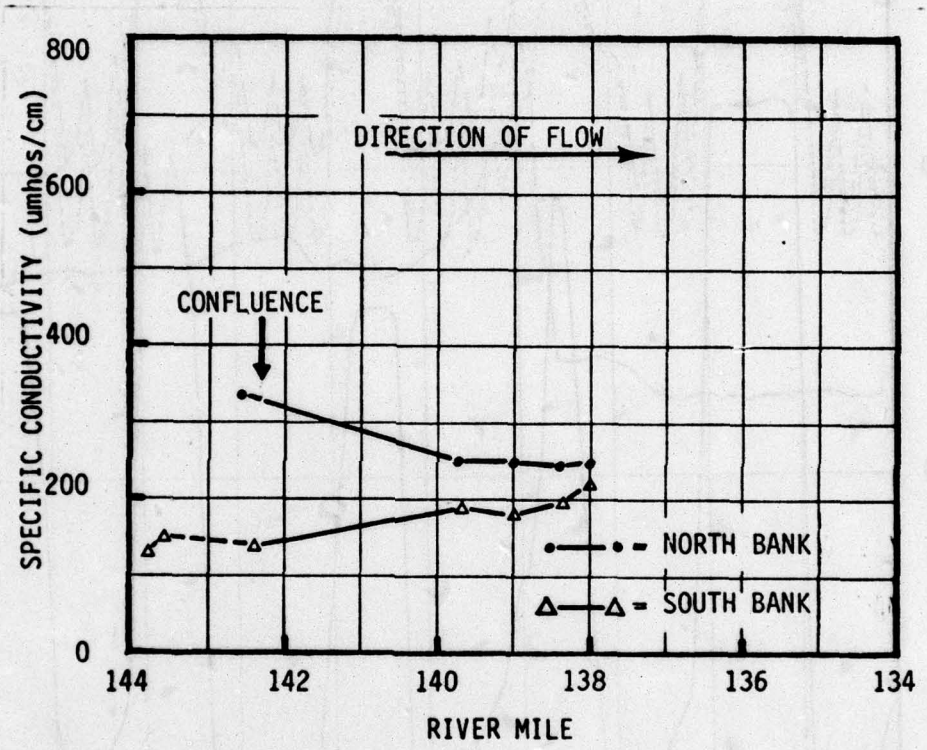

FIGURE 8. CONDUCTIVITY PROFILES ADJACENT TO THE NORTH AND SOUTH BANKS OF THE HOLSTON RIVER DURING PEAK TURBINE DISCHARGE. JUNE 6, 1975.

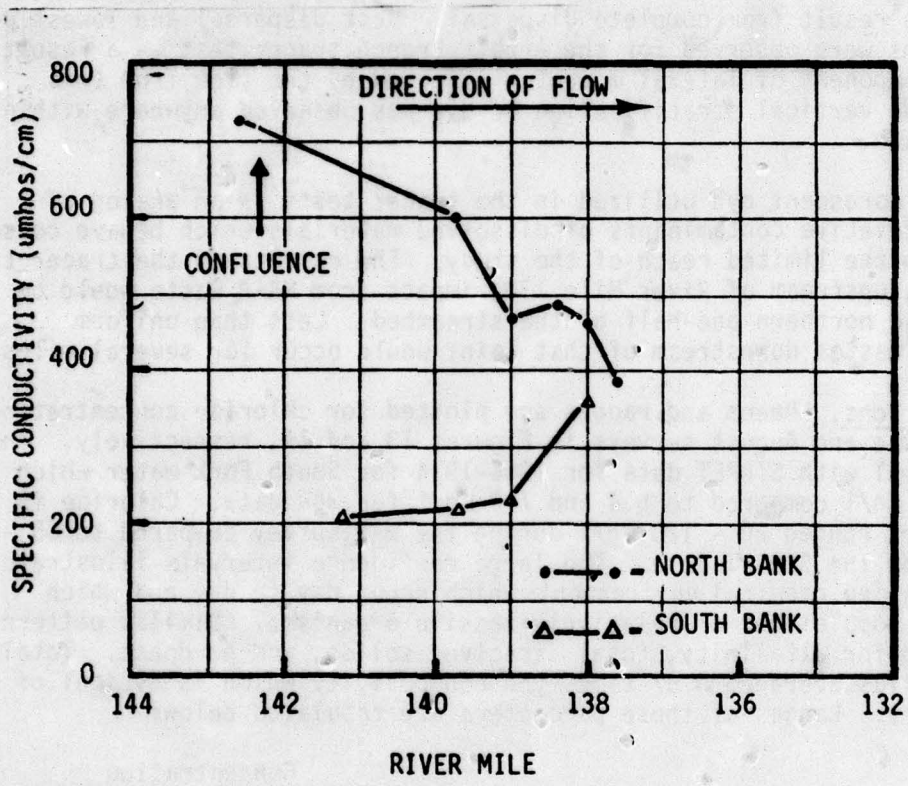

FIGURE 9. CONDUCTIVITY PROFILES ADJACENT TO THE NORTH AND SOUTH BANKS OF THE HOLSTON RIVER DURING MINIMUM TURBINE DISCHARGE. AUGUST 8, 1975.

Results of the tracer tests are presented in Figures 10, 11 , and 12, for the three respective outfall zones: Station 7, Station 8, and Arnott Branch. Tracer concentrations are expressed as multiples of a uniform cross-sectional concentration assuming a completely dispersed system. Based upon this, peak concentrations in a profile must equal or exceed 1.0. Some concentration anomalies are evident -- these are a consequence of the changing flow regimes and outfall discharges unavoidably encountered during the tracer tests.

Essentially all dye was confined to the northern one-half of the streambed to a distance of 1 - 1.5 miles downstream of the dye injection point; peak concentrations within this zone ranged from 2.3 to 9.4 times a level calculated to result from complete dispersal. Best dispersal and lowest peak concentrations were observed for the Arnott Branch tracer test -- a result of the larger component of lateral momentum imparted by the flow from this tributary. No vertical stratification of dye was observed anywhere within the study reach.

The fluorescent dye utilized in the tracer tests is an analog of soluble conservative contaminants of dissolved materials which behave conservatively within the limited reach of the study. The results of the tracer tests suggest that, upstream of River Mile 138, impact from HAAP waste would be limited to the northern one-half of the streambed. Less than uniform dispersal of wastes downstream of that point would occur for several miles.

Major Ions. Means and ranges are plotted for chloride concentrations during the June and August surveys in Figures 13 and 14, respectively. They correspond well with STORET data for 1966-1974 for South Fork water which averaged 7.6 mg/l compared to 5.4 and 7.0 mg/l for WAR data. Chloride in the North Fork ranged 20 - 120 mg/l during the WAR survey compared to 85 - 2,433 mg/l for the STORET data. The large confidence intervals illustrate the widely varied chemical environments which occur day to day and which could affect populations of relatively sessile organisms. Similar patterns were observed for alkalinity, total dissolved solids, and hardness. Total dissolved solids averaged 0.67 times the conductivity which is typical of natural waters. Ranges of these parameters are tabulated below:

		Concentration	
		June 1975	August
Total Dissolved Solids (mg/l)	North Fork	175 - 425	392 - 576
	South Fork	107 - 132	106 - 296
	Station 12	75 - 208	108 - 239
Total Hardness (mg $CaCO_3$/l)	North Fork	108 - 170	162 - 179
	South Fork	68 - 85	73 - 105
	Station 12	88 - 119	84 - 117
Alkalinity (mg $CaCO_3$/l)	North Fork	86 - 110	70 - 90
	South Fork	60 - 66	62 - 80
	Station 12	72 - 87	69 - 77

Discharges from HAAP did not significantly affect concentrations of these ions. Total hardness in the North Fork ranged much higher during the period

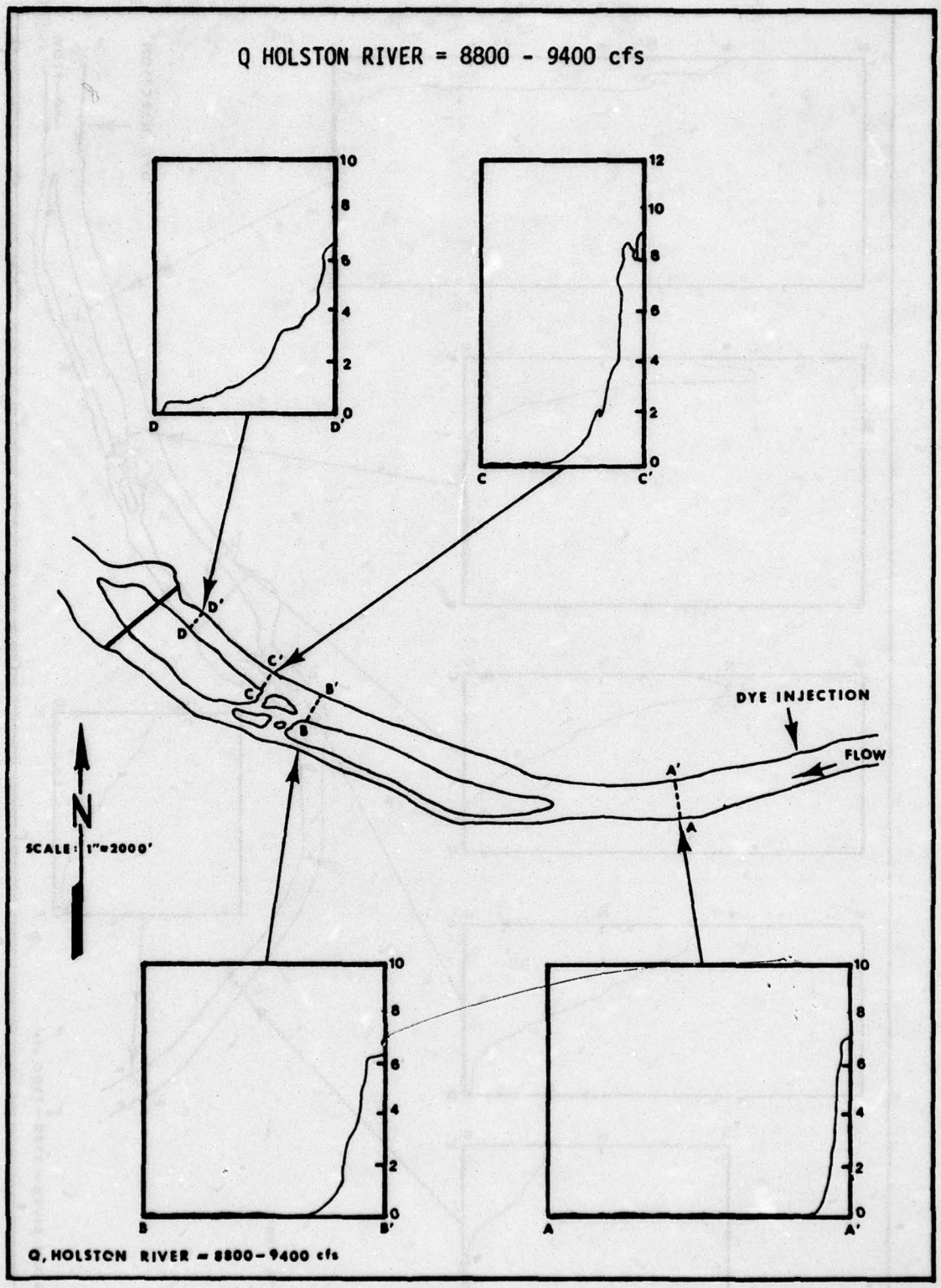

FIGURE 10. TRANSVERSE RHODAMINE DYE PROFILES RECORDED IN THE HOLSTON RIVER ON 2 JUNE 1975 DURING THE STATION 7 OUTFALL ZONE TRACER STUDY.

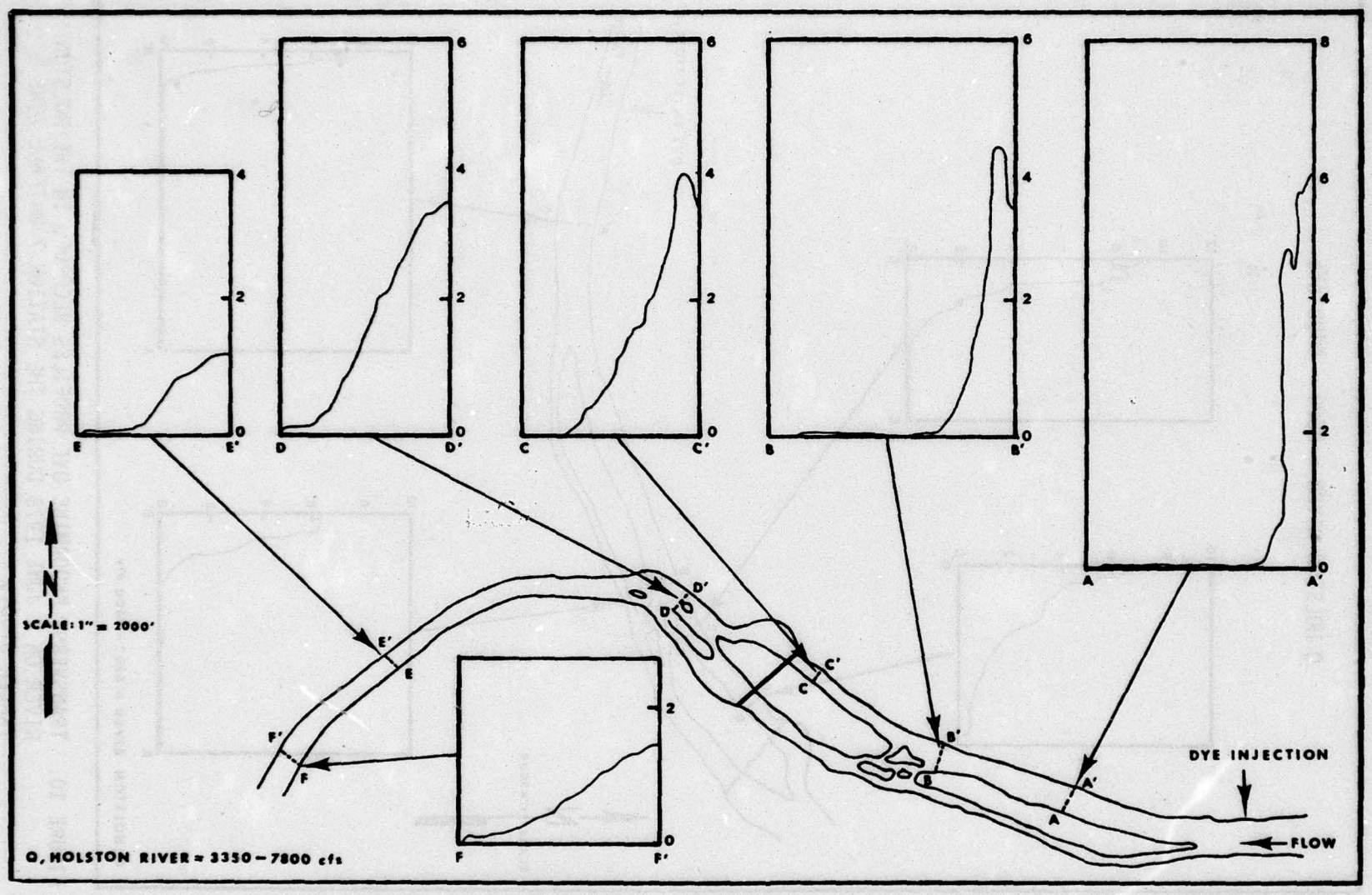

FIGURE 11. TRANSVERSE RHODAMINE DYE PROFILES RECORDED IN THE HOLSTON RIVER ON 3 JUNE 1975 DURING THE STATION 8 OUTFALL ZONE TRACER STUDY.

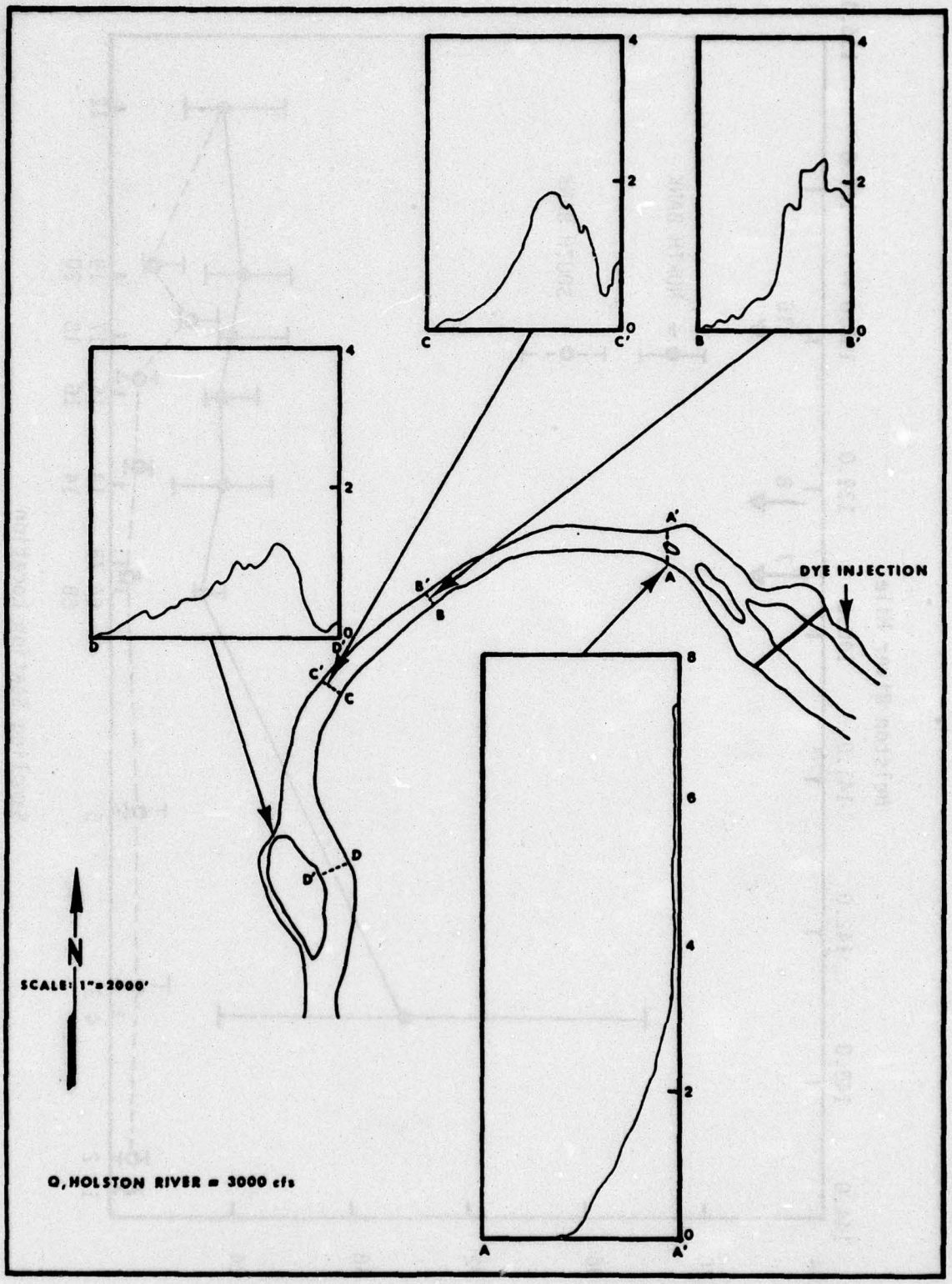

FIGURE 12. TRANSVERSE RHODAMINE DYE PROFILES RECORDED IN THE HOLSTON RIVER ON 4 JUNE 1975 DURING THE ARNOTT BRANCH OUTFALL ZONE TRACER STUDY.

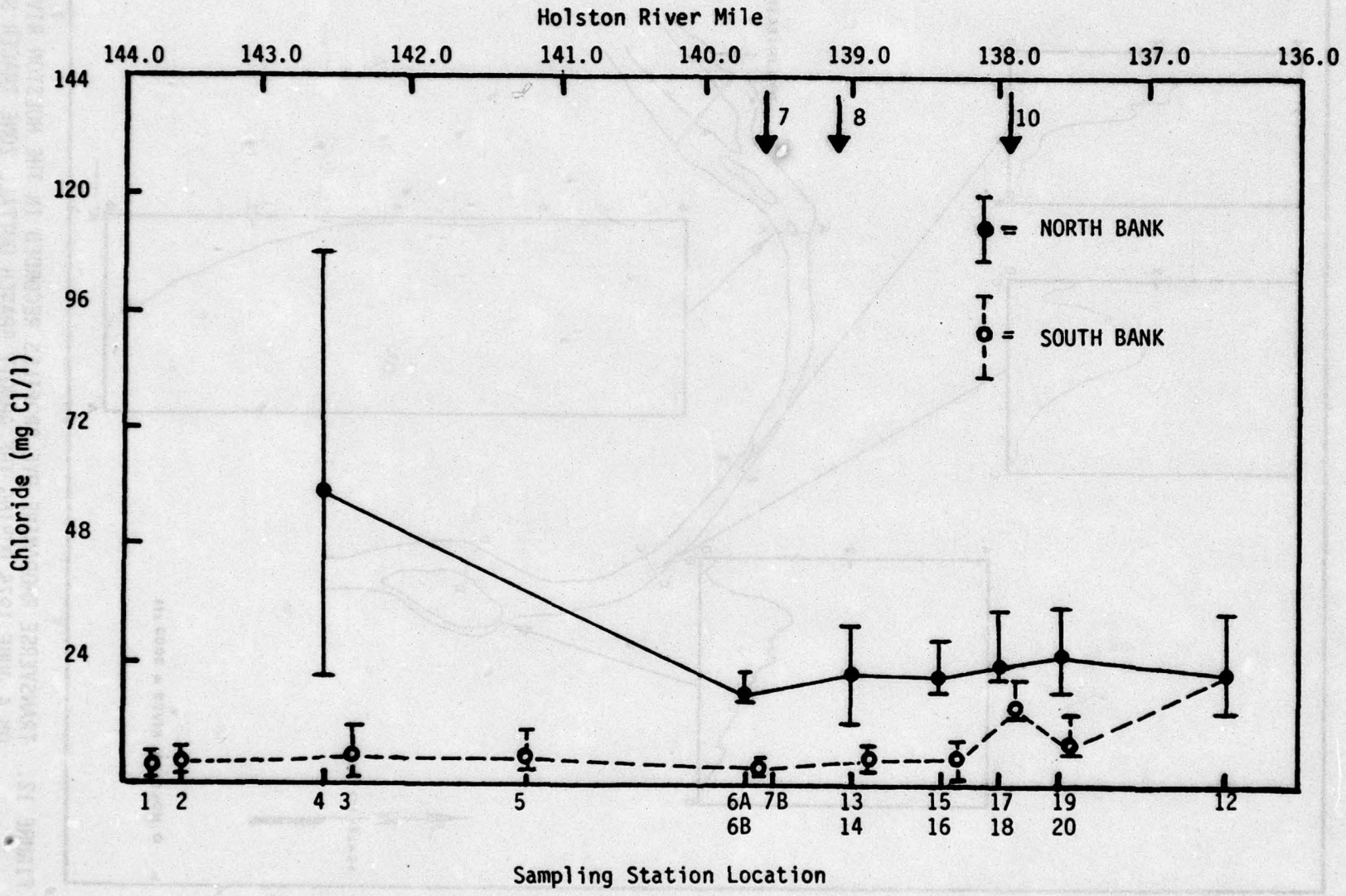

FIGURE 13. CHLORIDE CONCENTRATIONS IN THE HOLSTON RIVER AT HAAP - JUNE, 1975.

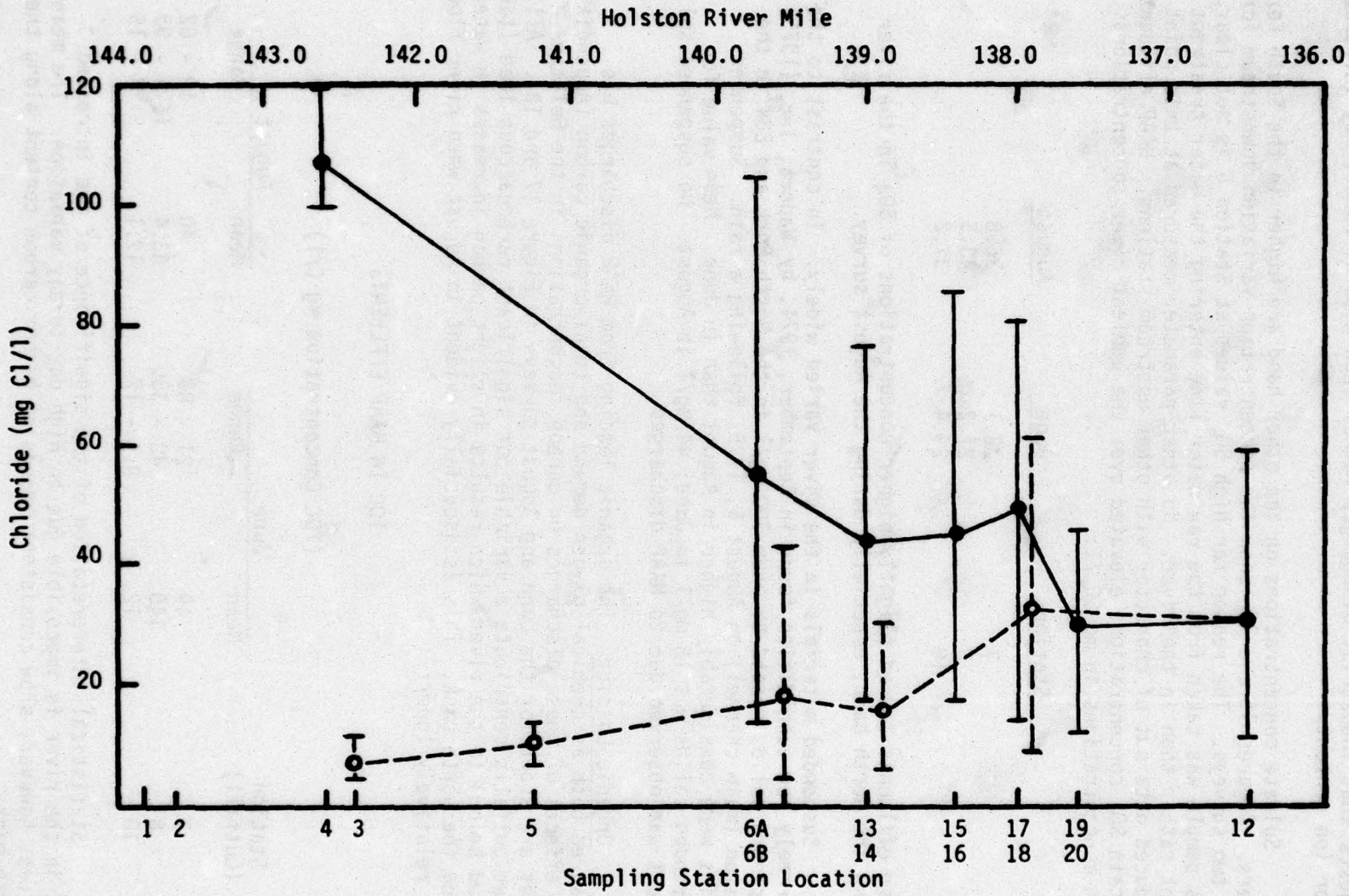

FIGURE 14. CHLORIDE CONCENTRATION IN THE HOLSTON RIVER AT HAAP, AUGUST, 1975.

1966 - 1974 (STORET) (68 - 2,416 mg $CaCO_3$/l) than during the WAR survey which suggests that industrial discharges rather than natural runoff may influence major ion content.

Sulfate concentrations on the other hand are higher in the South Fork waters. Figures 15 and 16 show the concentration variation downstream for the two surveys. The reason for high SO_4 values at Station 5 is not clear. This sample was taken from the raw water line entering the water treatment plant rather than in the river. No other parameter measured at this point produced data out of character with other upstream stations. HAAP effluents contain SO_4 concentrations elevated over the ambient river concentrations. Mean concentrations in mg SO_4/l:

Station	June	August
7	32.1	36.8
8	27.2	43.5
10	29.4	37.2

These effluents caused slightly higher concentrations of SO_4 in the river along the north bank, especially during the August survey.

Suspended materials in the river varied widely. In contrast to the extremely low turbidities found in September, 1974, by Wapora, Inc. (1975) suspended solids ranged to over 300 mg/l in the North Fork and 284 in the Holston (main channel) on August 6, 1975, following a rain. Suspended solids were considerably higher in August than in June. Mean value for suspended solids was 18 mg/l in June; 44 mg/l in August. No suspended solids impact was observed due to HAAP discharges.

Organic Loading. The organic loading from HAAP discharges was measured both as chemical oxygen demand and total organic carbon (Appendix A-3). The effects of these discharges on carbon concentrations in the Holston River are shown for the June and August surveys in Figure 17 and 18 . All three outfalls contribute a variable but significant carbonaceous load (tabulated below) to the river which results in slight carbon increases in water along the north bank. This is especially evident in August when river flow was relatively lower:

TOC IN HAAP EFFLUENTS

(TOC Concentration mg C/l)

Station (Outfall)	June		August	
	Mean	Range	Mean	Range
7	49	21 - 88	40	19 - 62
8	146	40 - 330	43.4	16.5 - 93
10	12	8.5 - 17	12.1	7 - 15

Statistical interpretation of the significance of the increased TOC in the river is impossible due to high day-to-day variation. The mean values, however, show consistent trends of higher carbon content along the North bank.

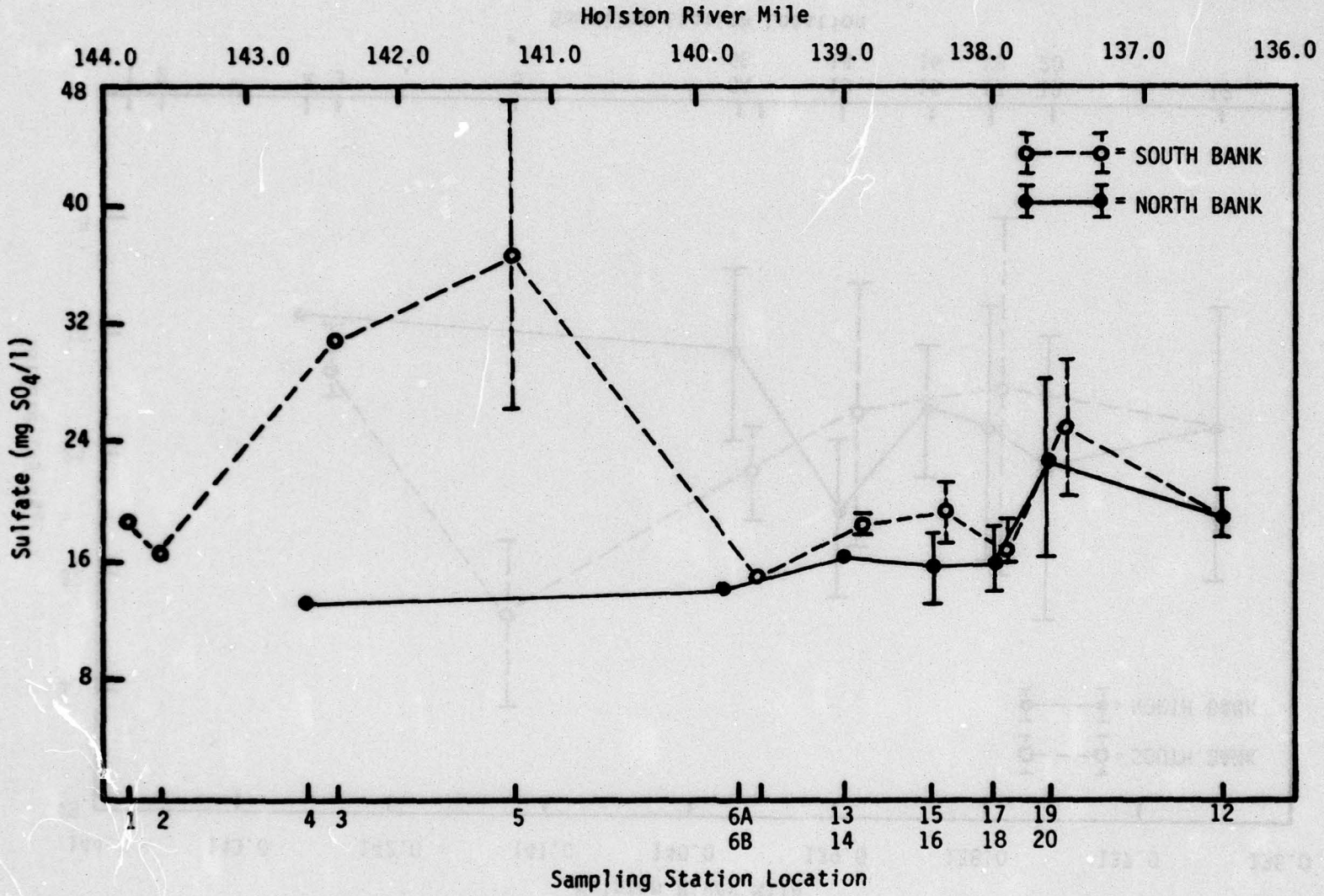

FIGURE 15. SULFATE CONCENTRATION IN THE HOLSTON RIVER AT HAAP, JUNE, 1975 .

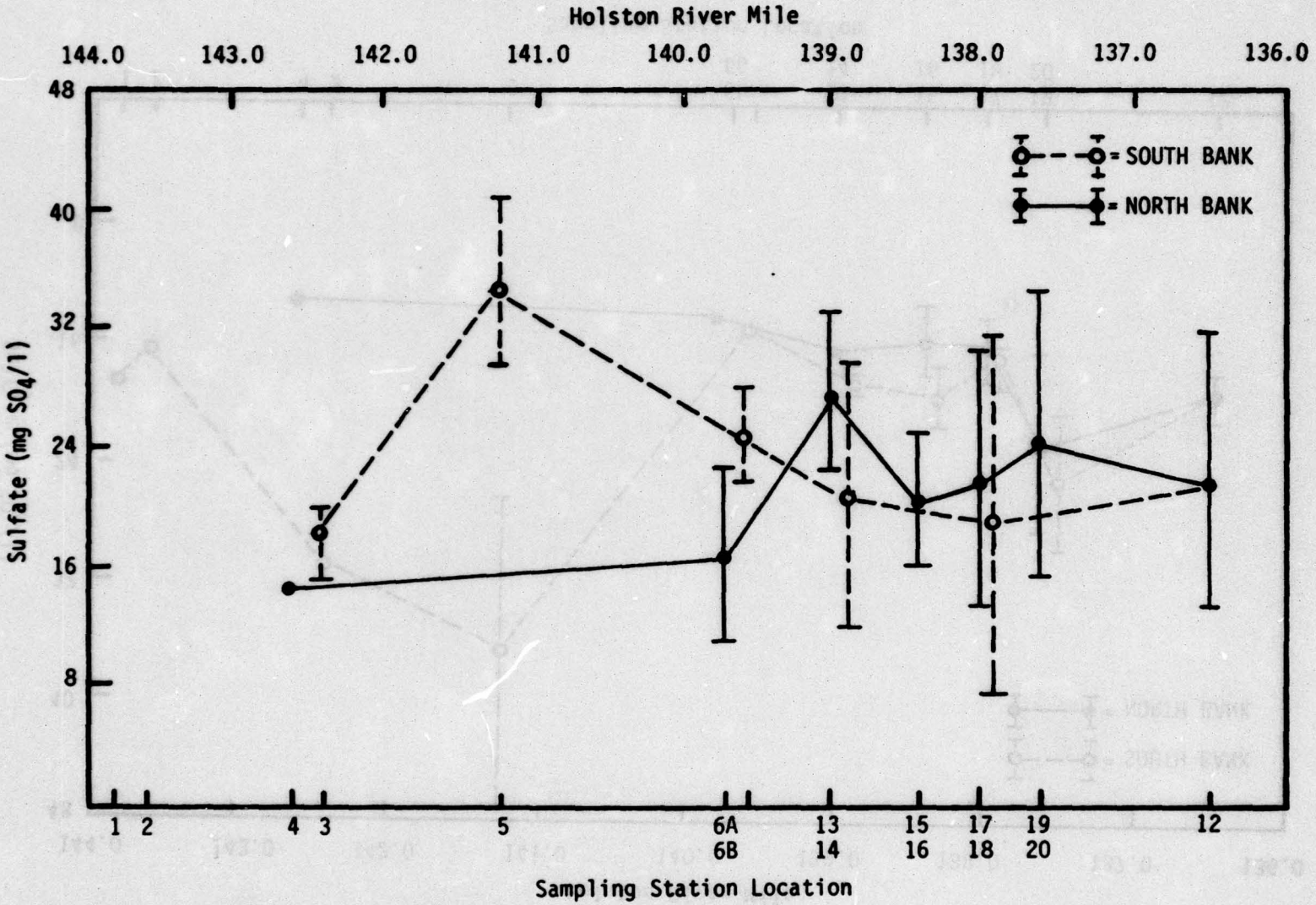

FIGURE 16. SULFATE CONCENTRATION IN THE HOLSTON RIVER AT HAAP, AUGUST, 1975, MEAN VALUE AND RANGE OF VARIATION.

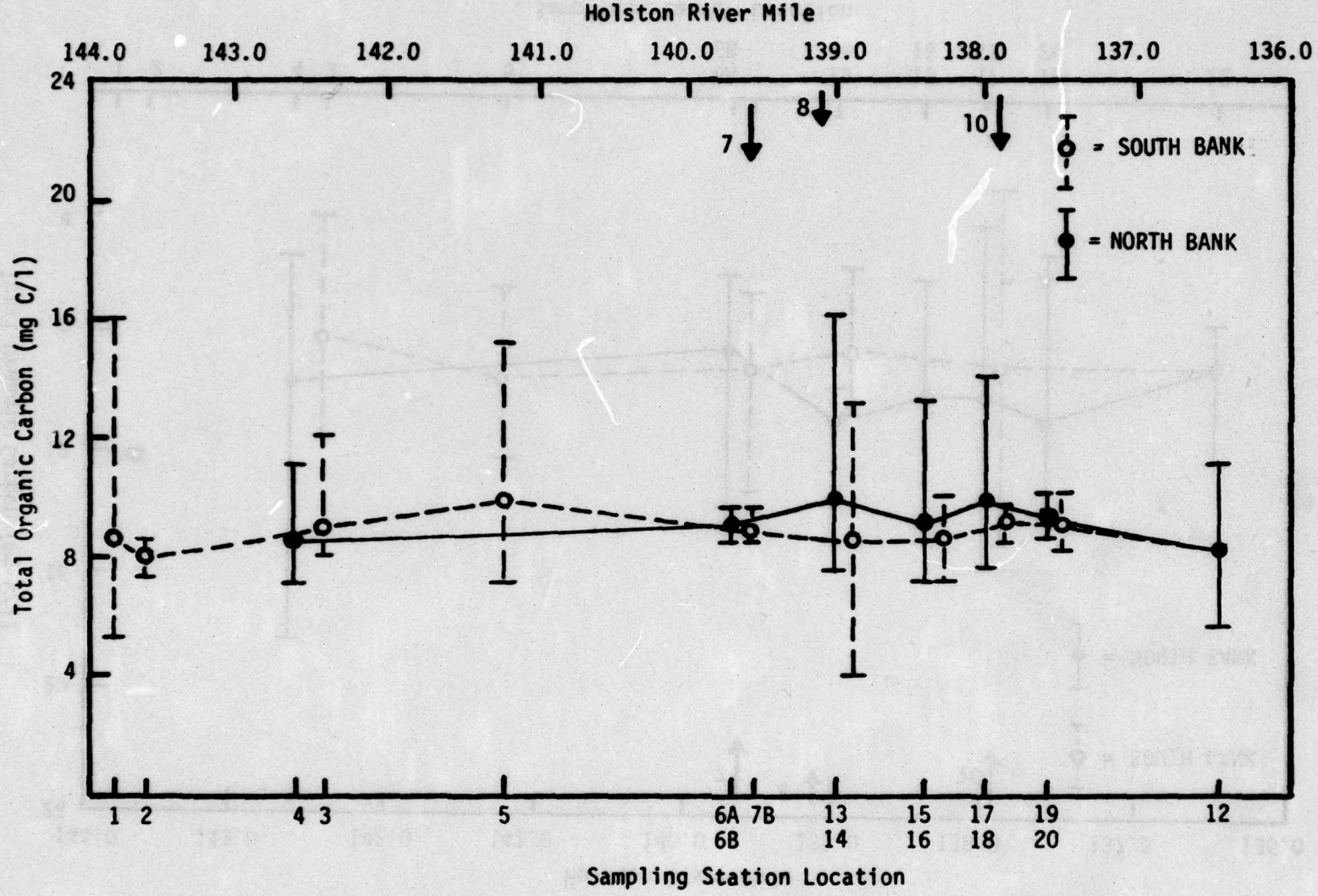

FIGURE 17. TOTAL ORGANIC CARBON IN THE HOLSTON RIVER AT HAAP, JUNE, 1975, MEAN VALUE AND RANGE OF VARIATION.

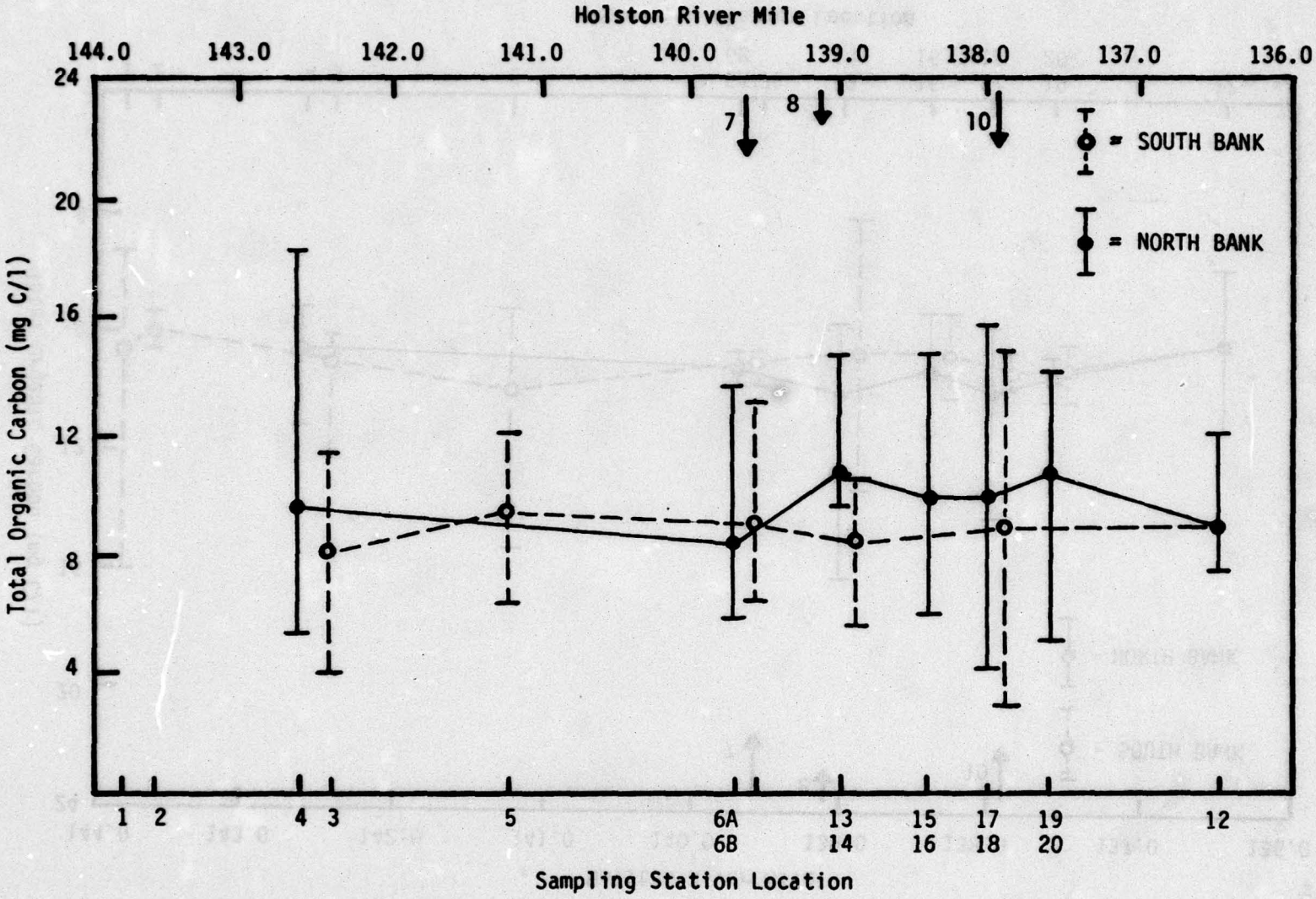

FIGURE 18. TOTAL ORGANIC CARBON IN THE HOLSTON RIVER AT HAAP, AUGUST, 1975
MEAN VALUE AND RANGE OF VARIATION.

Carbon input from Arnott Branch (Station 10) was lowest in terms of concentration but the high flow of the creek relative to the upstream outfalls provided substantial carbon loading. The mean carbon level of the river (8 to 10 mg C/l) indicates a BOD of 9 - 12 (Medina, 1972) indicative of significant oxygen demand. The upper ranges of TOC in the river water suggest that this reach is periodically heavily loaded by oxygen demanding materials.

Nitrogen and Phosphorus. The major nutrient input from HAAP is nitrogen. Data for the June and August surveys, tabulated in Appendix A-3, reflect nitrate values similar to those in the July, 1969 EPA survey (EPA, 1972) and the September, 1974 study (WAPORA, Inc. 1975), and indicate a significant increase in concentrations in the north side of the river at Station 20 downstream of Arnott Branch. This is especially evident during the August survey (Figures19 and 20). This impact was a direct result of the discharge from the nitric acid area via Arnott Branch. This stream had a NO_3-N concentration of 3.5 mg N/l in June and nearly 9 mg N/l in August. High concentrations of NO_3-N were also discharged at outfalls 7 and 8. However, comparison of Stations 3 and 4 (South and North Fork) confirm that the majority of the ambient NO_3-N load is carried in the South Fork.

Total Kjeldahl nitrogen and ammonia concentrations are also high in this reach of the Holston and represent loading from Kingsport. Kjeldahl nitrogen data from the June and August 1975 surveys are presented in Figures 21 and 22. In August the major impact comes from the 3.8 mg/l discharge from Arnott Branch causing increased concentrations of reduced nitrogen at Station 20. During the 1969 EPA study, concentrations at that point were 3.6 mg N/l along the north bank, 1.7 mg N/l along the south. In June concentrations in the river represent an oxygen demand as NOD[1] of about 3.5 mg/l and 5.5 mg/l for June and August.

Ammonia concentrations in general followed similar patterns as TKN for the two 1975 surveys. The TKN and NH_3-N levels correspond with overall means from STORET data from 1966 - 1974 in terms of concentrations in North and South Fork waters. Nitrogen loading was higher during the July, 1969 EPA study and suggested a major impact from HAAP. Kjeldahl and ammonia concentrations immediately below Arnott Branch were significantly higher on the HAAP side of the river (Table 4). The lower nitrogen concentrations found overall in the 1975 WAR survey may reflect improved nitrogen removal upstream.

Phosphate concentrations were higher in the South Fork water than in the North Fork. Concentration ranges for the North Fork water (Station 4) were 0.03 - 0.04 mg P/l in June; 0.04 - 0.15 in August compared to 0.08 - 0.28 mg P/l and 0.08 - 0.28 mg P/l for Station 3 in the South Fork for the same period. These ranges correspond with the results of the 1969 EPA study and the 1966 - 1974 STORET records. Effluent concentration ranges are tabulated below and indicate that some phosphate load is generated by HAAP discharges. The quantities discharged do not appear to elevate ambient river concentrations.

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[1] 4.57 x mg N/l (EPA, 1972)

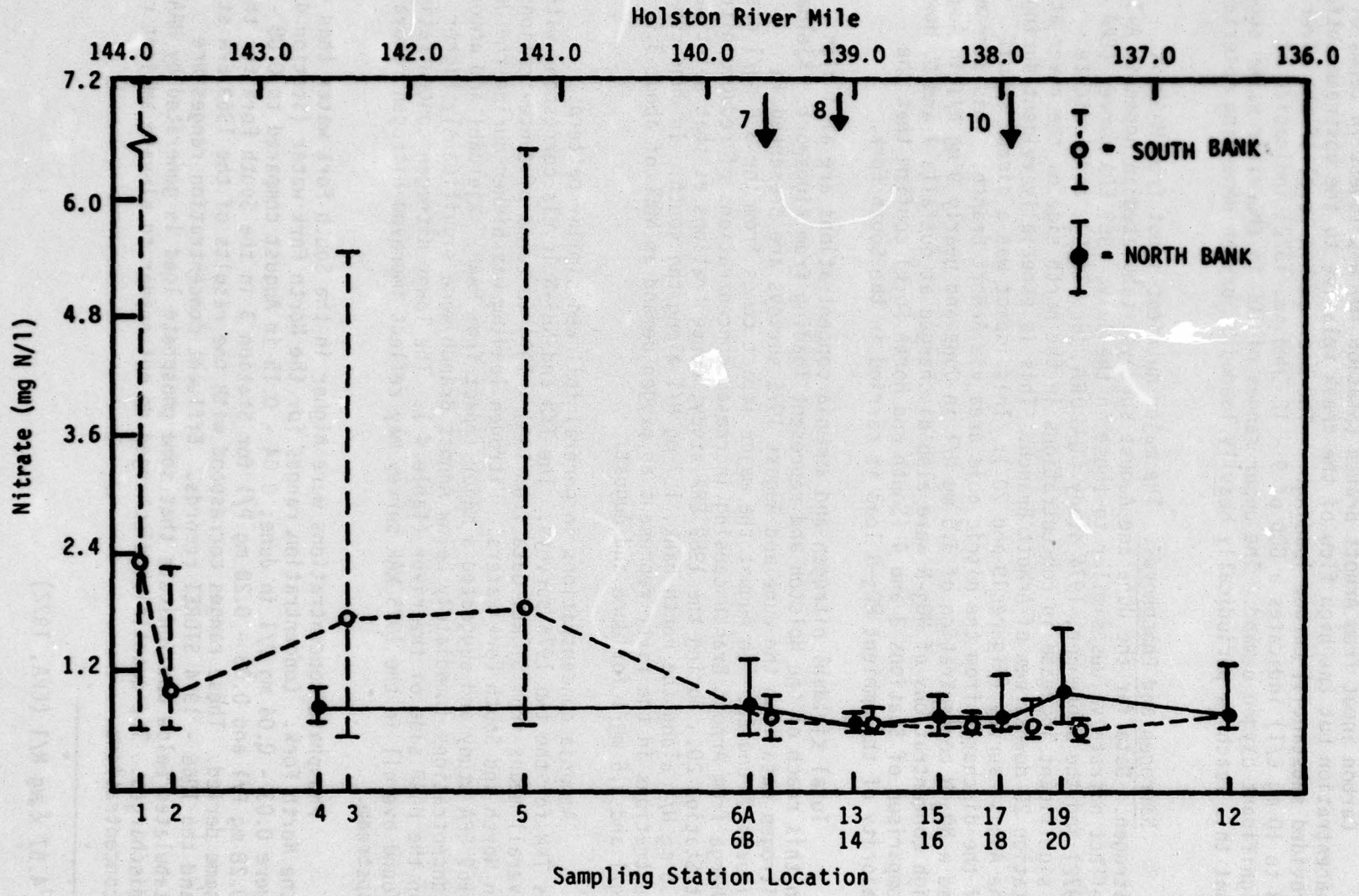


FIGURE 19. NITRATE NITROGEN IN THE HOLSTON RIVER AT HAAP, JUNE, 1975, MEAN VALUE AND RANGE OF VARIATION.

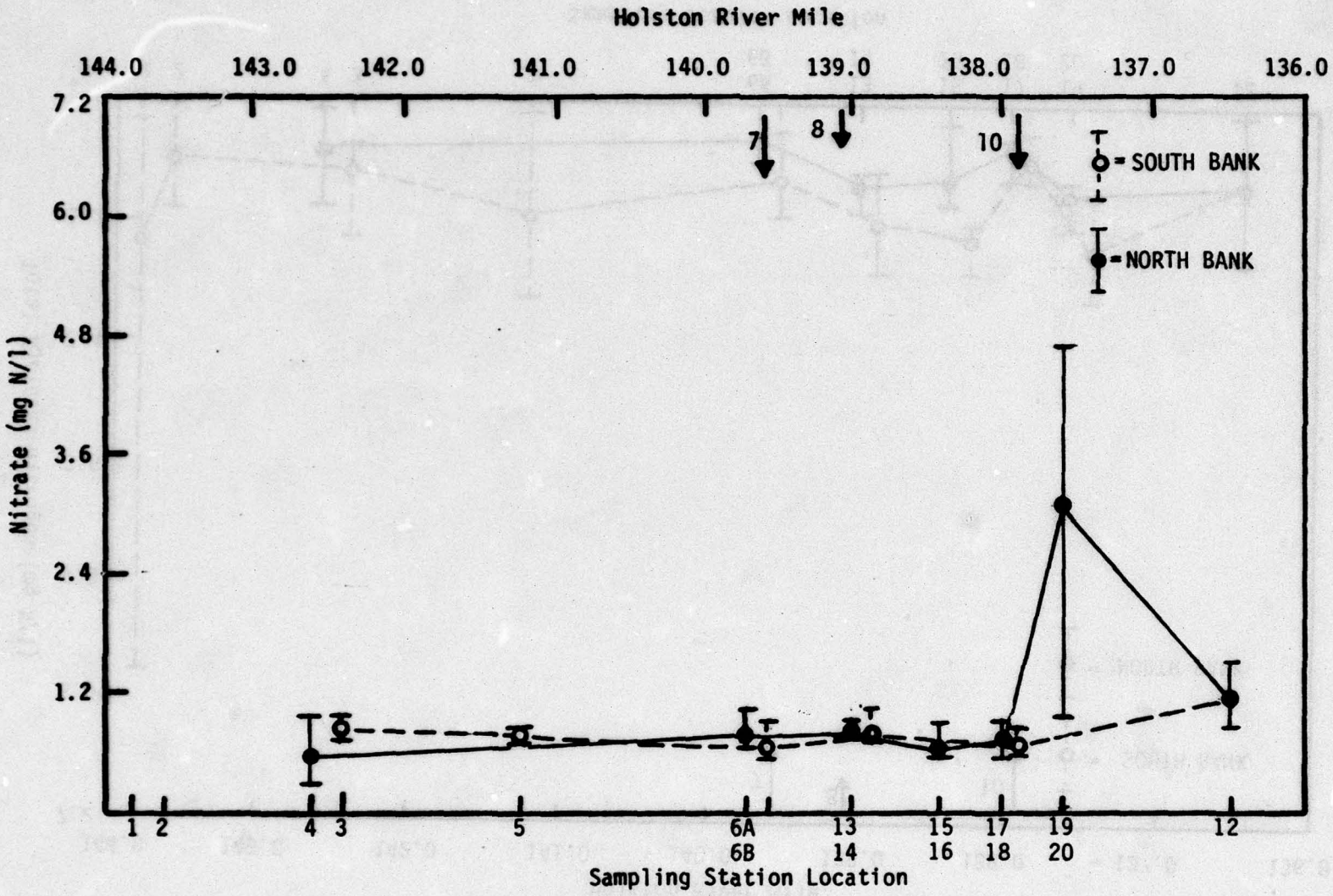


FIGURE 20. NITRATE NITROGEN IN THE HOLSTON RIVER AT HAAP, AUGUST 1975, MEAN VALUE AND RANGE OF VARIATION.

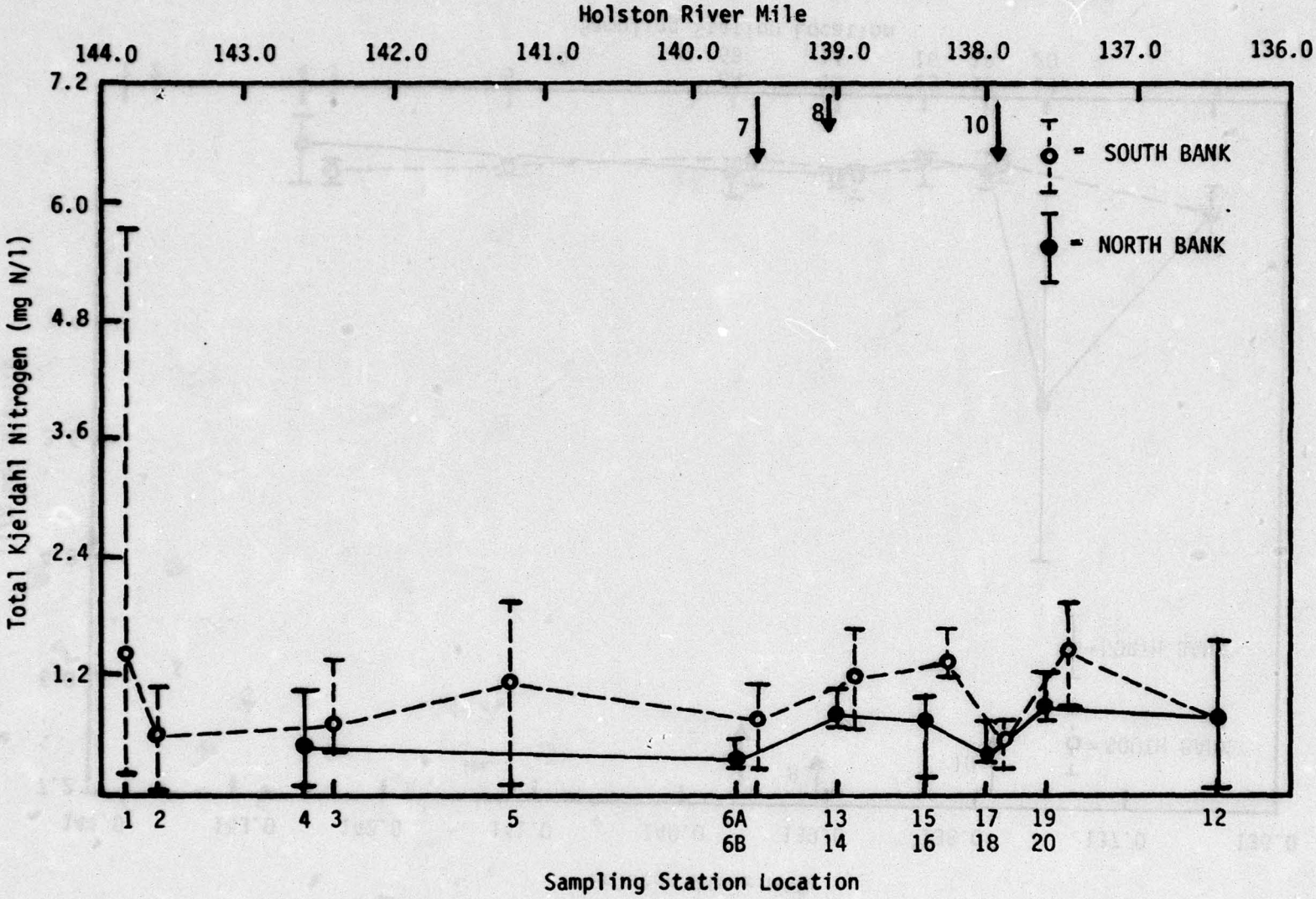


FIGURE 21. TOTAL KJELDAHL NITROGEN IN THE HOLSTON RIVER AT HAAP, JUNE, 1975
MEAN VALUE AND RANGE OF VARIATION.

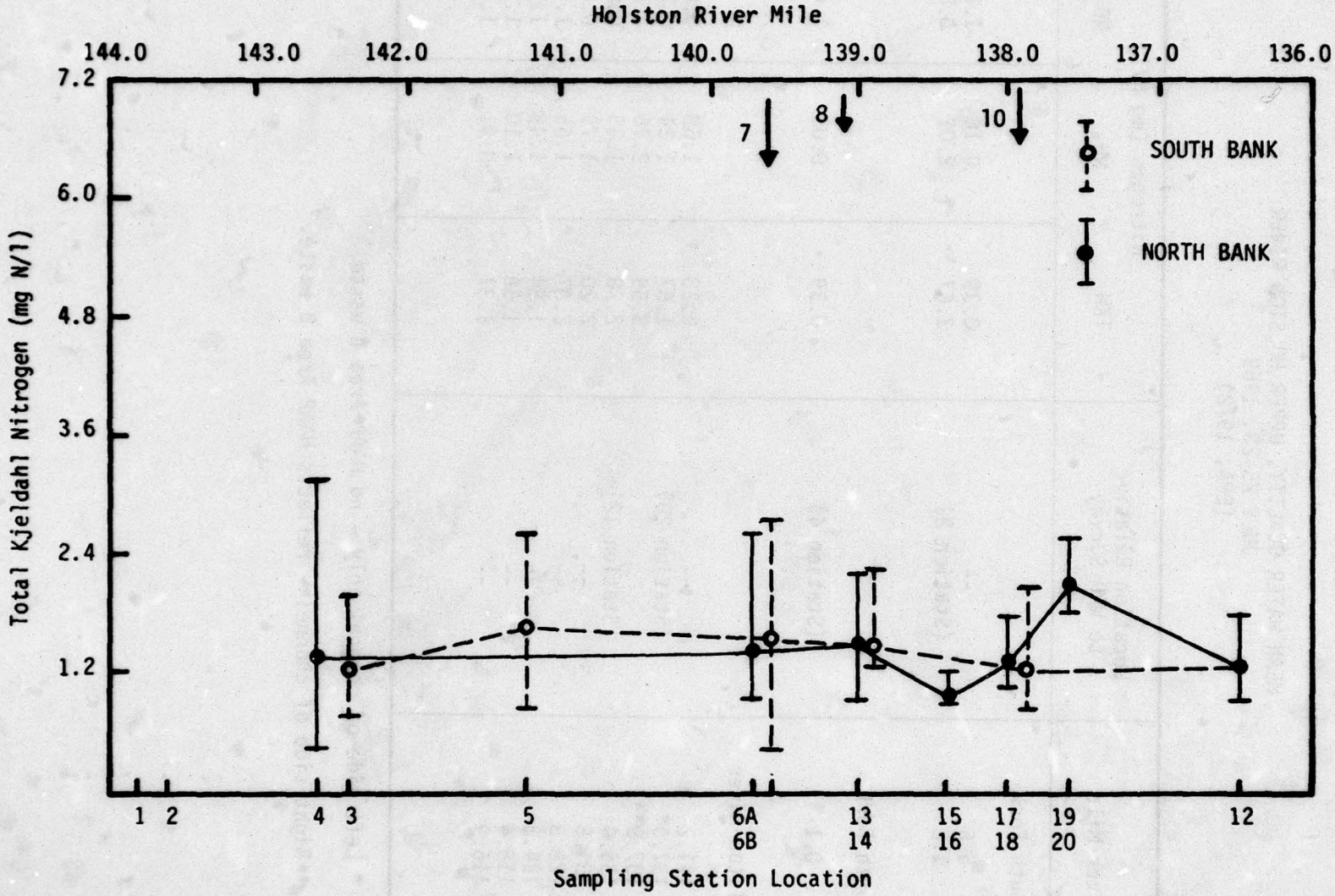


FIGURE 22. TOTAL KJELDAHL NITROGEN IN THE HOLSTON RIVER AT HAAP, AUGUST, 1975, MEAN VALUE AND RANGE OF VARIATION.

TABLE 4

MEAN WATER QUALITY, UPPER HOLSTON RIVER
JULY 25-28, 1969
(EPA, 1972)

River Mile	Location Relative to WAR Survey	Nitrogen (mg N/l) TKN	NH_3	NO_3-N
South Fork				
5.6	--	0.39	0.10	1.25
1.2	(Station 2)	2.67	2.01	0.88
North Fork				
0.1	(Station 4)	0.39	0.08	1.01
Holston River				
141.2	--	2.28	1.68	0.63
137.9*	(Station 20)	1.67	1.24	0.60
137.9**		3.59	2.76	2.38
135.4	(Station 12)	2.28	1.85	0.95
131.5	--	2.20	1.79	0.89
128.3	--	2.07	1.65	1.02
124.3	--	1.84	1.48	1.13
118.4	--	1.58	1.10	1.31
115.9	--	1.37	0.91	1.49

* Left side of channel only - no HAAP Area B waste.

**Right side of channel - reflects HAAP Area B waste.

Total Phosphorus (mg P/l)

Station	June Mean	June Range	August Mean	August Range
7	0.08	0.05-0.13	0.19	0.13-0.20
8	0.07	0.04-0.13	0.13	0.06-0.15
10	0.16	0.13-0.23	0.21	0.16-0.25

Figure 23 illustrates phosphorus levels in the impact area and shows a gradual mixing of North and South Fork water. It may be noted that PO_4 concentrations are significantly lower along the north bank.

Trace Metals. Appendix A-6 contains the results for trace metal analysis of river water and HAAP effluents and shows that munitions waste does not contribute significantly to the burden of metals in the Holston River. Wapora, Inc (1975) found mercury concentrations measuring from 5 µg/l upstream of HAAP to 63 µg/l below the plant. This was not substantiated in the 1975 surveys nor in examination of STORET data reporting mercury analyses from 1966 to 1974 at selected sites in the study reach. These latter EPA data showed concentrations ranging from 0.5 to 3.4 µg/l.

In the June 1975 survey, 93 water samples were analyzed for mercury. These showed no detectable (>0.5 µg/l) mercury. During August, 2 out of 36 contained detectable mercury, but only one was above the 2 µg/l proposed drinking water standard (Public Law 92-583).

The 1972 EPA survey of waste sources indicated heavy manganese loading associated with Tennessee Eastman Corporation discharge. STORET data for the period 1972 to 1974 confirmed manganese values >0.1 mg/l as far downstream as mile 131.5.

Daily variation of iron was 0.17 to 0.6 mg/l, slightly above the recommended limits (EPA, 1973) to 0.3 mg/l for drinking water. Lead was below detection with the exception of one sample at Station 7 in June (73 µg/l). This level could not be confirmed by further sampling.

Significant lead discharges, however, do occur from Tennessee Eastman Corporation (STORET, 1972-1974) which cause concentrations downstream of about 50 µg/l. The September, 1974 Wapora, Inc. (1975) study detected 20 to 50 µg/l Pb in waters of this reach.

One value for copper, 36 µg/l (Station 8, August Survey) was above the 15 - 33 µg/l recommended value for protection of most sensitive aquatic life. Zinc concentrations ranging from 2 to 91 µg/l during the study were well below EPA recommended criteria (150 µg/l in hard and 5 µg/l in soft waters).

The remaining metals (Cd, Cr^{+6}, and Ni) were either undetectable or found in concentrations well below environmentally significant levels. These data and STORET data support the following conclusion: heavy metal toxicity is unlikely to be associated with HAAP effluents.

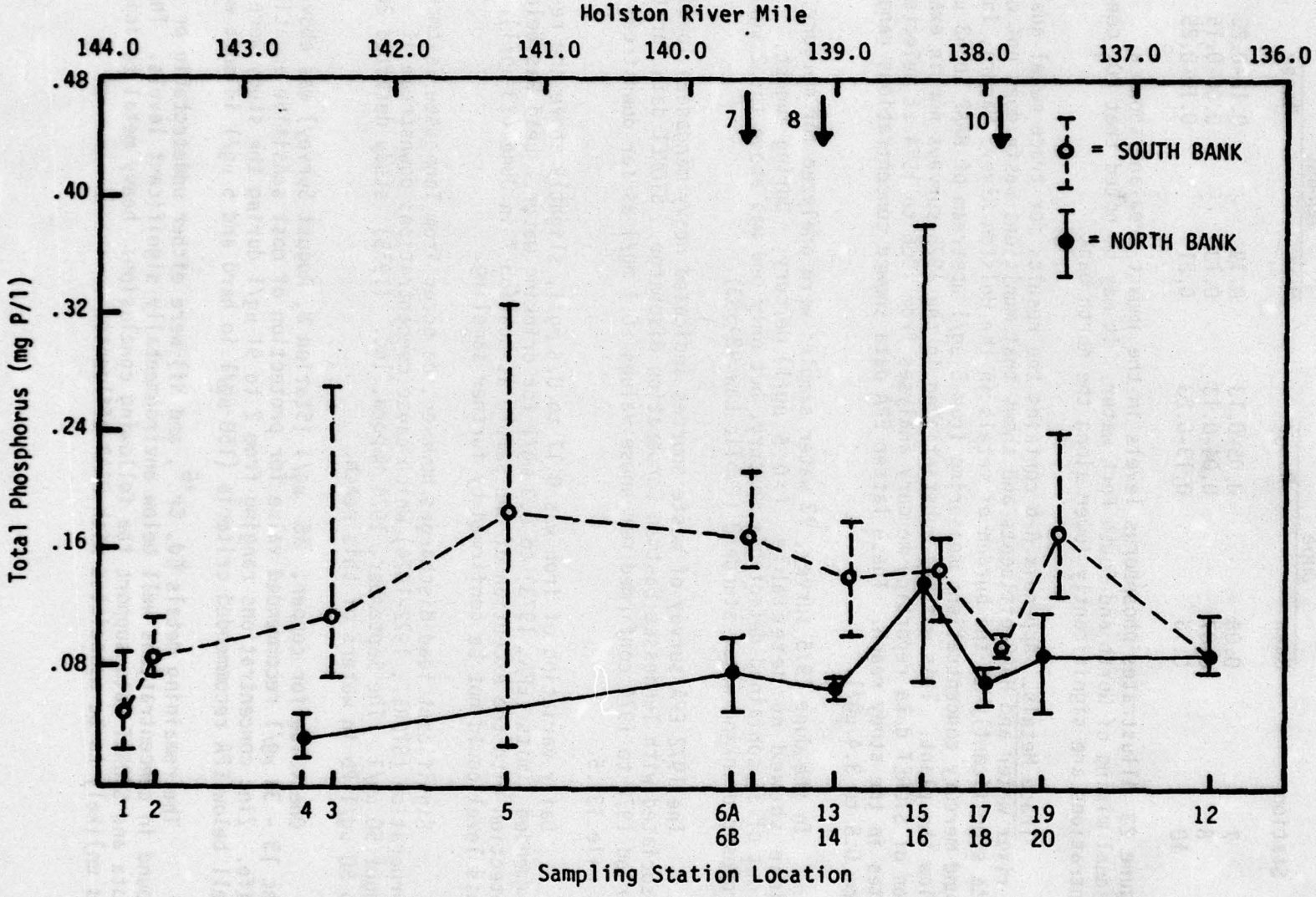


FIGURE 23. TOTAL PHOSPHOROUS CONCENTRATION IN THE HOLSTON RIVER AT HAAP, JUNE, 1975, MEAN VALUE AND RANGE OF VARIATION.

Munitions and Solvents. The results of analyses of RDX, TNT, and two percursors of TNT, 2,4-DNT and 2,6-DNT are tabulated in Appendix A-V. Overall the major munitions discharge consisted of RDX residues both for the June and August surveys. Trinitrotoluene residues were detectable in quantifiable amounts only in the effluent streams at Stations 7 and 8 and in the river at Station 7B. No HMX was found in the samples (detection limit of 1 mg/l as measured by thin layer chromatography). RDX residues were found in effluent samples at concentrations ranging to 8,200 µg/l at Station 7, 8,780 µg/l at Station 8, and 635 µg/l at Station 10 (Arnott Branch). Figures 24 and 25 show the distribution of RDX residues. Mimimum quantifiable concentration of RDX was 5 µg/l.

In June the peak river concentration occurred at Station 14 (150 µg/l) located downstream of outfalls Station 7 and 8 (Figure 24). Downstream stations generally showed lower concentrations with a maximum of 27 µg/l occurring at Station 12. Consistently higher concentrations of RDX were found in the north bank stations confirming that the effluents do not disperse rapidly in the river.

RDX residues were generally higher in the river during August (Figure 25). Again, the same pattern of decreasing concentrations was observed from Stations 14 to 12. Levels of RDX in the river on the north bank ranged from a maximum of 70 µg/l at Station 12.

The values of 5 and 150 µg/l at Station 6A on 8/6/75 and 8/8/75 are considered to have resulted from contamination either in the field or during extraction. Trinitrotoluene was detectable in quantifiable amounts during the August survey in the effluents at Stations 7 and 8 and in the river at Station 7-B. Minimum detectable TNT or dinitrated toluene was 1 µg/l. No HMX was detected in the August survey.

Records of waste discharge data for 1974 and 1975 based on monthly grab samples by the Holston Defense Corporation generally ranged higher than the data from the WAR survey. Mean RDX-HMX-TNT residues in Arnott Branch were 1,500 µg/l, standard deviation nearly 5,000 µg/l, mostly as RDX. Munitions production line means averaged as follows:

	Mean of all Lines
RDX-HMX-TNT	5,800 µg/l
TNT	980 µg/l
RDX	3,950 µg/l
HMX	870 µg/l.

RDX was always discharged. Trinitrotoluene and especially HMX are apparently not always present in the discharge.

In the Wapora study (1975) no TNT residues >100 µg/l were found in the river. RDX or HMX concentrations were not determined.

Production line effluents also contain significant quantities of acetone and cyclohexanone. Not quantitated in the WAR survey, these compounds probably

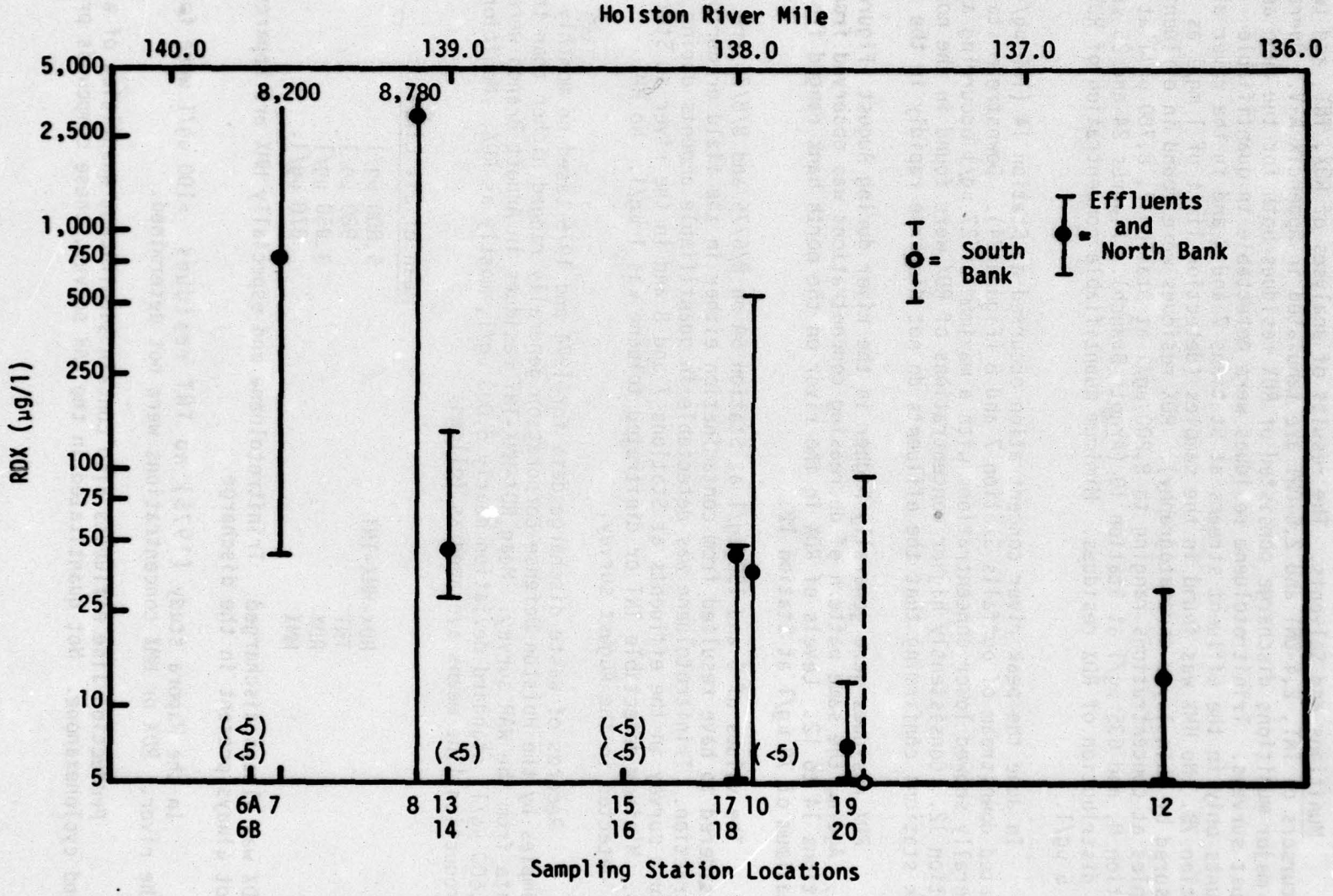


FIGURE 24. MEDIAN VALUES AND CONCENTRATION RANGE FOR RDX RESIDUES IN THE HOLSTON RIVER, ARNOTT BRANCH AND MUNITIONS EFFLUENTS, JUNE, 1975.

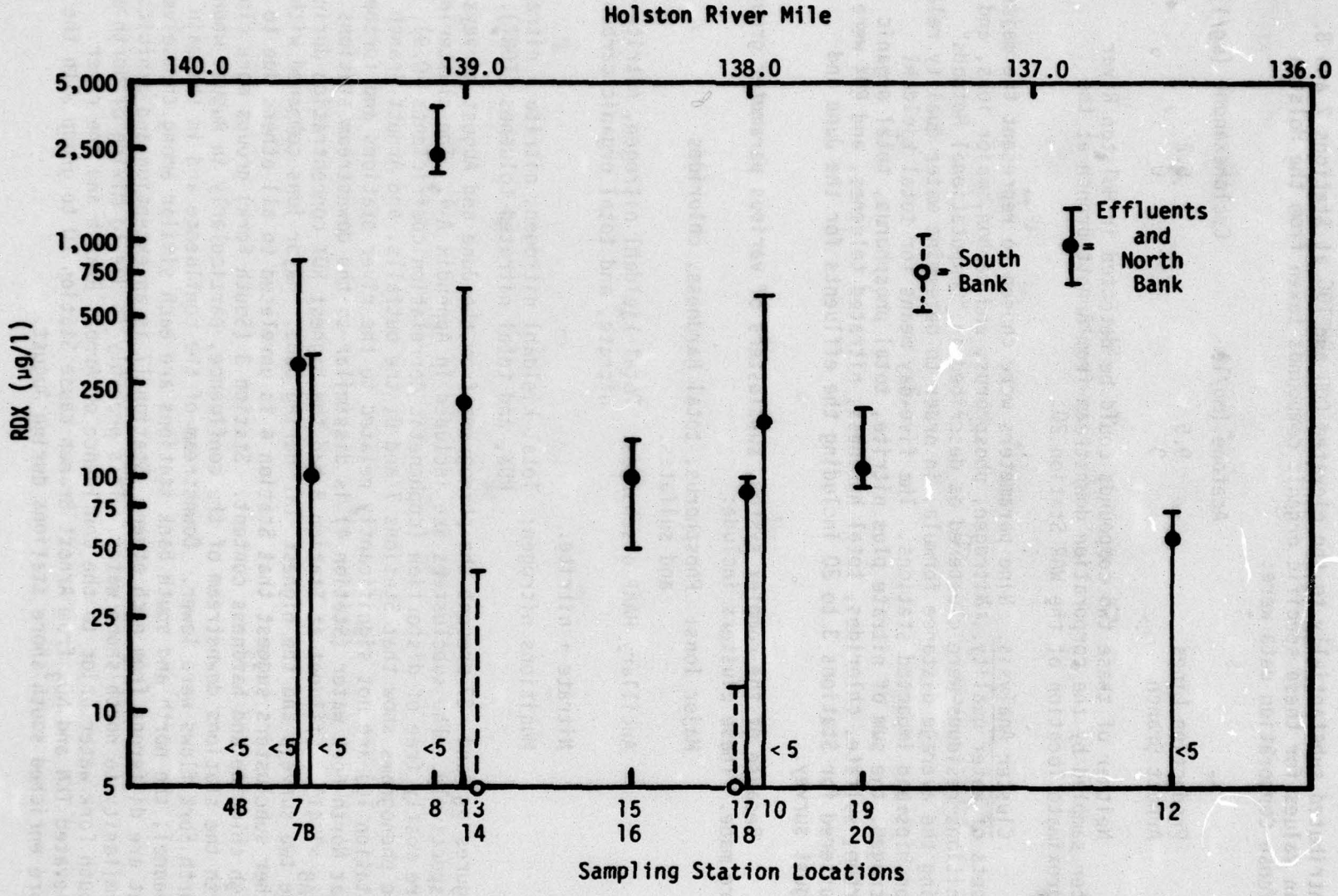


FIGURE 25. MEDIAN VALUES AND CONCENTRATION RANGE FOR RDX RESIDUES IN THE HOLSTON RIVER, ARNOTT BRANCH, AND MUNITIONS EFFLUENTS, AUGUST, 1975.

contributed substantially to the elevated COD and TOC at Stations 7 and 8. Mean values for these specific organic compounds taken from the Holston Defense Corporation data were:

	Acetone (mg/l)	Cyclohexanone (mg/l)
Production Lines	9.5	6.2
Arnott Branch	0	0

Neither of these two compounds could be detected in Holston River water sampled by the corporation downstream from Arnott Branch at the approximate location of the WAR Station 20.

Cluster Analysis. Nine parameters were chosen to represent the major facets of water quality. Nitrogen, phosphorus, and carbon, major ions, and munitions residues were clustered as described in "Computational Methods" using the average distance formula, in order to determine water quality relationships and impacted stations. The five-day means for total kjeldahl nitrogen, the sum of nitrate plus nitrite, total phosphorus, total organic carbon, sulfate, chlorides, total hardness, nitrated toluenes, and RDX were clustered for Stations 3 to 20 including the effluents for the June and August survey.

Because of the complex system, subclusters of various parameter groups were made. These clusters include:

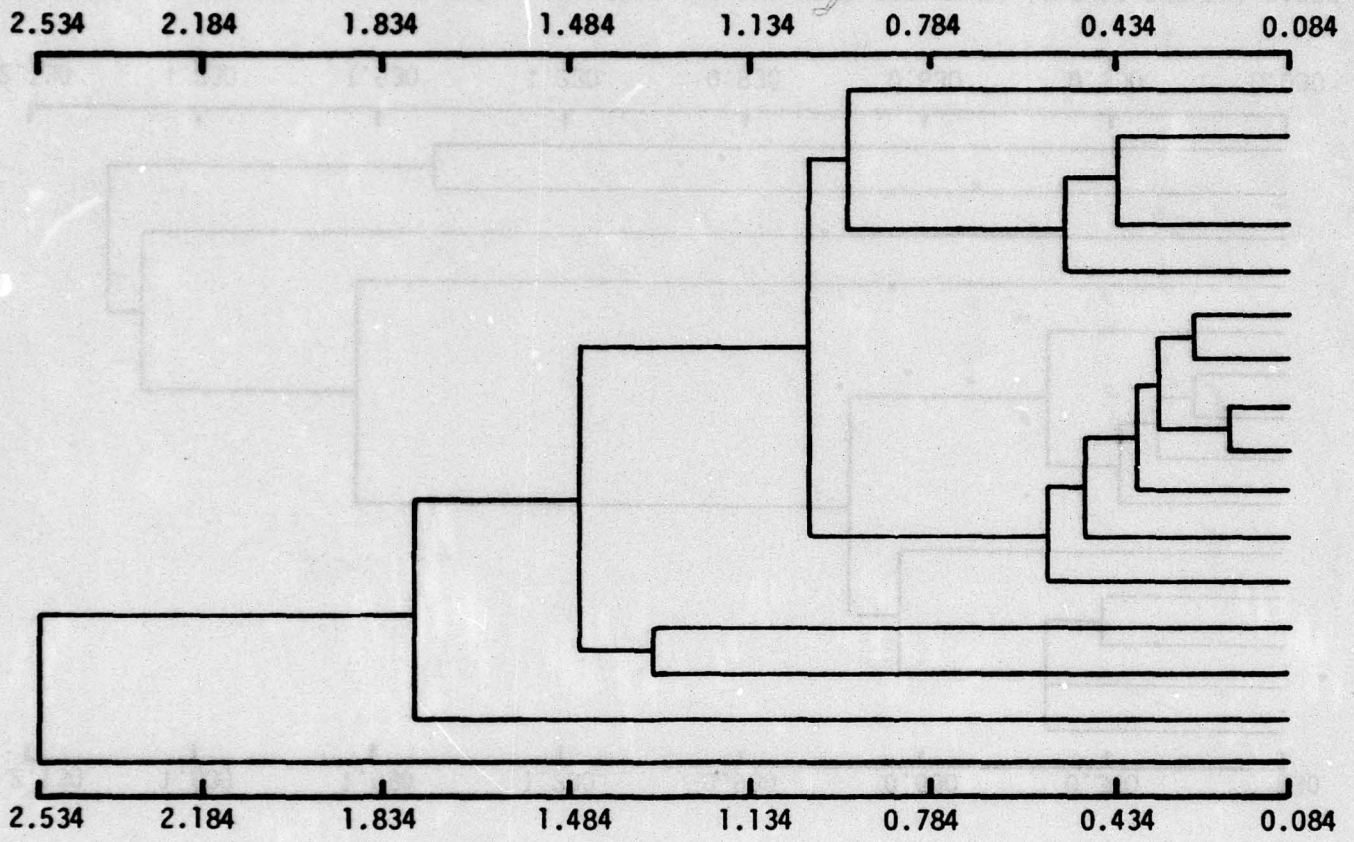
Major Ions: Phosphorus, total hardness, chlorides and sulfates.

Ancillary HAAP discharges: Total kjeldahl nitrogen, nitrite + nitrate, and total organic carbon.

Nitrate + nitrite.

Munitions nitrogen: Total kjeldahl nitrogen, nitrite + nitrate, RDX, and total nitrated toluenes (TONT).

Figures 26 and 27 present the phenograms from the June and August surveys, respectively. The subclusters are included in Appendix A-4. The clusterings were mostly free of distortion (cophenetic correlation coefficients >0.9). The phenograms show that Stations 7 and 8, the outfalls, and Arnott Branch (Station 10) are not significantly related to the river stations and further that North Fork water (Station 4) is dissimilar to the downstream stations (d_{AB} >1.41). Effluent at Station 8 had the highest RDX concentration during the two surveys and the highest TNT during June. Major ions compared with other subclusters suggest that Station 4 is unrelated to all others due to high chloride and hardness content. Station 3 (South Fork) groups more closely with the stations downstream of the confluence, particularly in August when North Fork flows were lower. Downstream of the confluence and in the main channel, the north and south bank stations are each similar among themselves but are different from each other. Station 17 is an exception and exhibits similarity to north shore water. This probably is due to mixing of North and South Fork water prior to the confluence of Arnott Branch and the river. Elevated TKN and NO_3 from Arnott Branch cause Station 20 to group with the more enriched south shore stations during August.



Station	Level
3	0.9073
6-A	0.4043
13	0.0903
15	0.5013
19	0.9767
6-B	0.2414
18	0.3260
14	0.2029
12	0.3523
17	0.4753
16	0.5321
20	1.4591
7	1.2995
10	1.7709
4	2.5337
8	

FIGURE 26. PHENOGRAM OF HOLSTON RIVER STATIONS AND HAAP EFFLUENTS (JUNE SURVEY) BASED ON TKN, NO_2 + NO_3, TOTAL PHOSPHORUS, TOC, Cl, SO_4, TOTAL HARDNESS, TNT, AND RDX. COPHENETIC CORRELATION COEFFICIENT, 0.952.

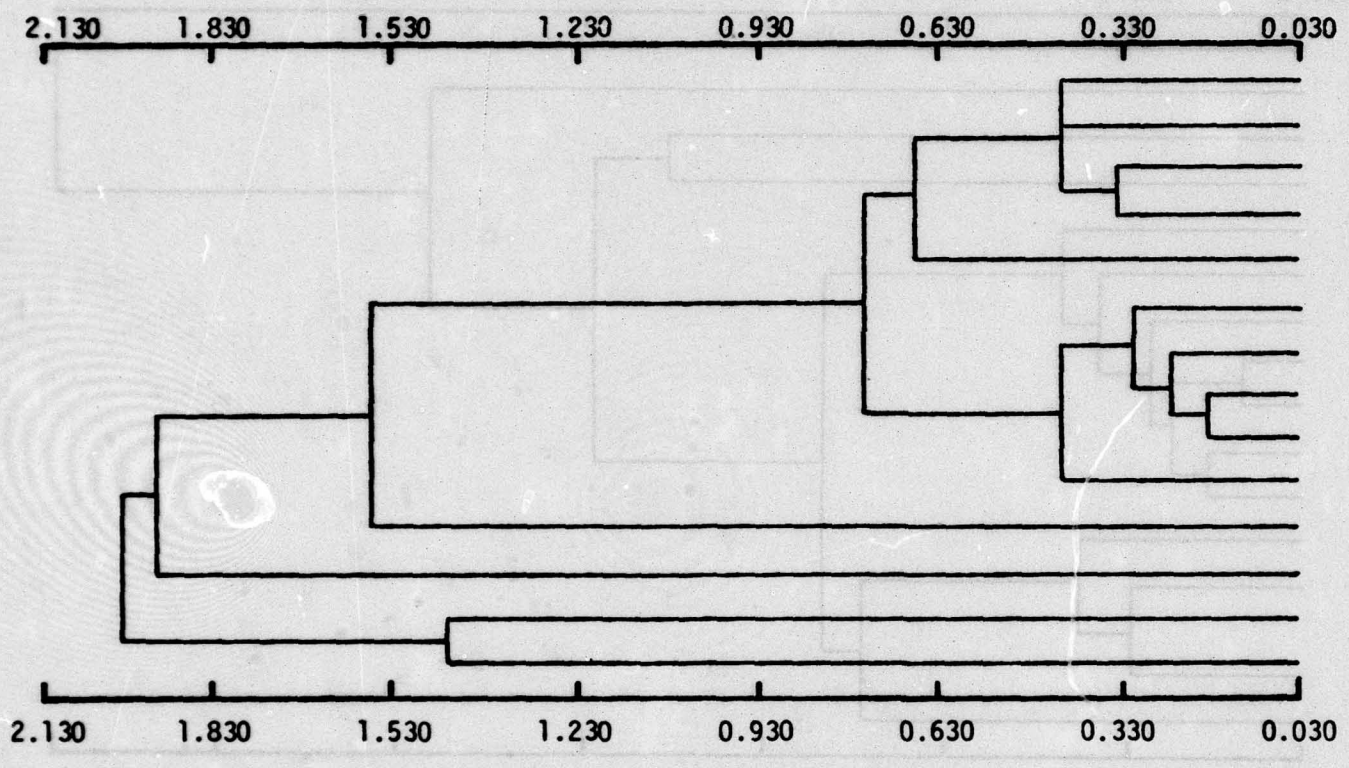


FIGURE 27. PHENOGRAM OF HOLSTON RIVER STATIONS AND HAAP EFFLUENTS (AUGUST SURVEY) BASED ON TKN, NO_2 + NO_3, TOTAL PHOSPHORUS, TOC, Cl, SO_4, TOTAL HARDNESS, TNT, AND RDX. COPHENETIC CORRELATION COEFFICIENT, 0.939.

A scatter diagram of NO_3 in Arnott Branch (Station 10) and Station 20 (Figure 28) shows good correlation between daily NO_3 values for these two points. Total kjeldahl nitrogen and TOC show similar correlations. Clustering of NO_2 and NO_3 shows Station 20 as being strongly influenced by the NO_3 source in Arnott Branch. Correlation was best during June when North Fork river flows were relatively stronger. Water quality at Station 12 is strongly influenced by river flow, grouping closely to the north shore stations in June and the south in August. During this latter period, South Fork major ion concentrations were closer to North Fork values, again illustrating the relationship between flow of the North and South Forks and water quality along the north and south bank of the main channel.

Characterization of Sediments

The strong and rapidly changing flow regime in the Holston River below the Ft. Patrict Henry Dam scours sediment in the main channel down to large rocks. Sediment enriched in carbon and nitrogen are deposited in back waters. Fifteen percent of the oxygen demand modeled in the 1969 EPA study (EPA, 1972) was considered to come from benthic demand. Ruane and Krenkel (1975) reported large numbers of Chironomids and Tubificids in the extensive shoreline sludge banks from the confluence of the North and South Forks down to approximately River Mile 136. These sediment beds also support luxuriant growths of aquatic plants. In the study reach (River Mile 142 - 136) these consisted principally of 7 species of the vascular plants Heteranthera dubia, Potamogeton pectinatus, P. nodosus, P. crispus, and Vallisneria americana were distributed mainly along the south bank of the river. Sediment nutrient (nitrogen, carbon, and phosphorus) values are tabulated in Appendix A-7. COD and nitrogen data are plotted in Figures 29 and 30 for the June and August surveys, respectively. Metal concentrations are also tabulated in Appendix A-7.

Sediment Nutrients. COD and TKN data show increasing enrichment proceeding downstream along the north bank and downstream of the outfalls to Station 18. By contrast the south bank stations show evidence of decreasing enrichment downstream of River Mile 139. The north bank of the river between River Mile 140 and 138 would be the more likely to accumulate sediment. Sediments along this bank show significant enrichment increasing downstream of the effluents. This may be due to HAAP discharges. Munitions residues also distribute along the north bank below Station 14. Although nutrient levels in sediment were higher along the north bank, the most luxurious growth of aquatic plants was distributed along the south bank.

Phosphorus was slightly higher on the north bank than the south, however, no definite downstream trends were apparent for either survey. Nitrate was distributed more or less evenly except for high values (>2,000 mg/l) immediately downstream and at the outfall for production lines 2, 3, 4, and 5. These overall nutrient data correspond closely to those reported by Wapora, Inc. (1975) for this reach of the river.

Trace Metals. A considerable portion of the elements resulting from cultural activities deposit into aquatic sediments. Primary among these are metal ions which may express toxic effects through bioaccumulation. Little

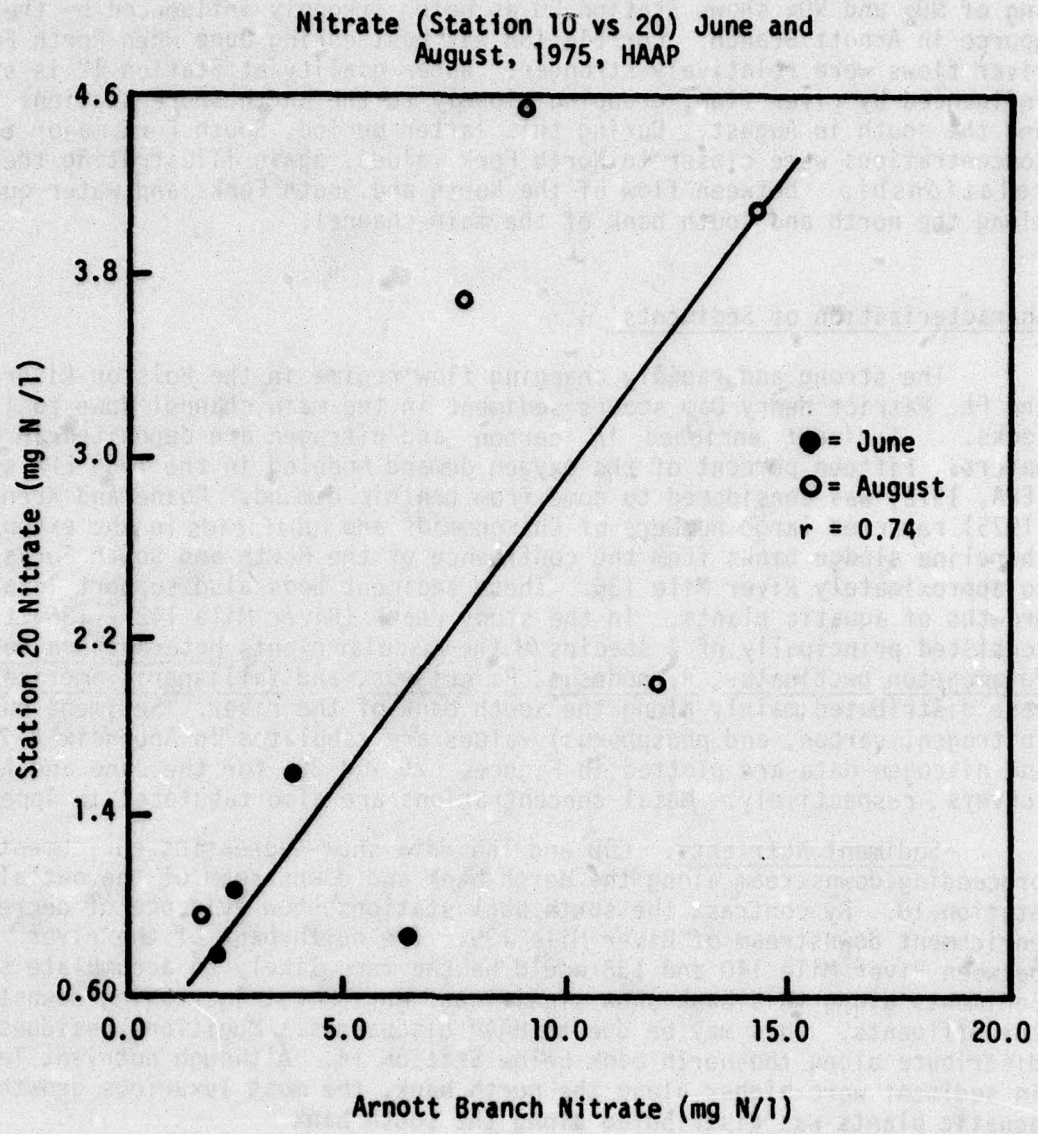


FIGURE 28. CORRELATION OF NO_3-N AT STATION 20 WITH NO_3-N FOUND IN ARNOTT BRANCH.

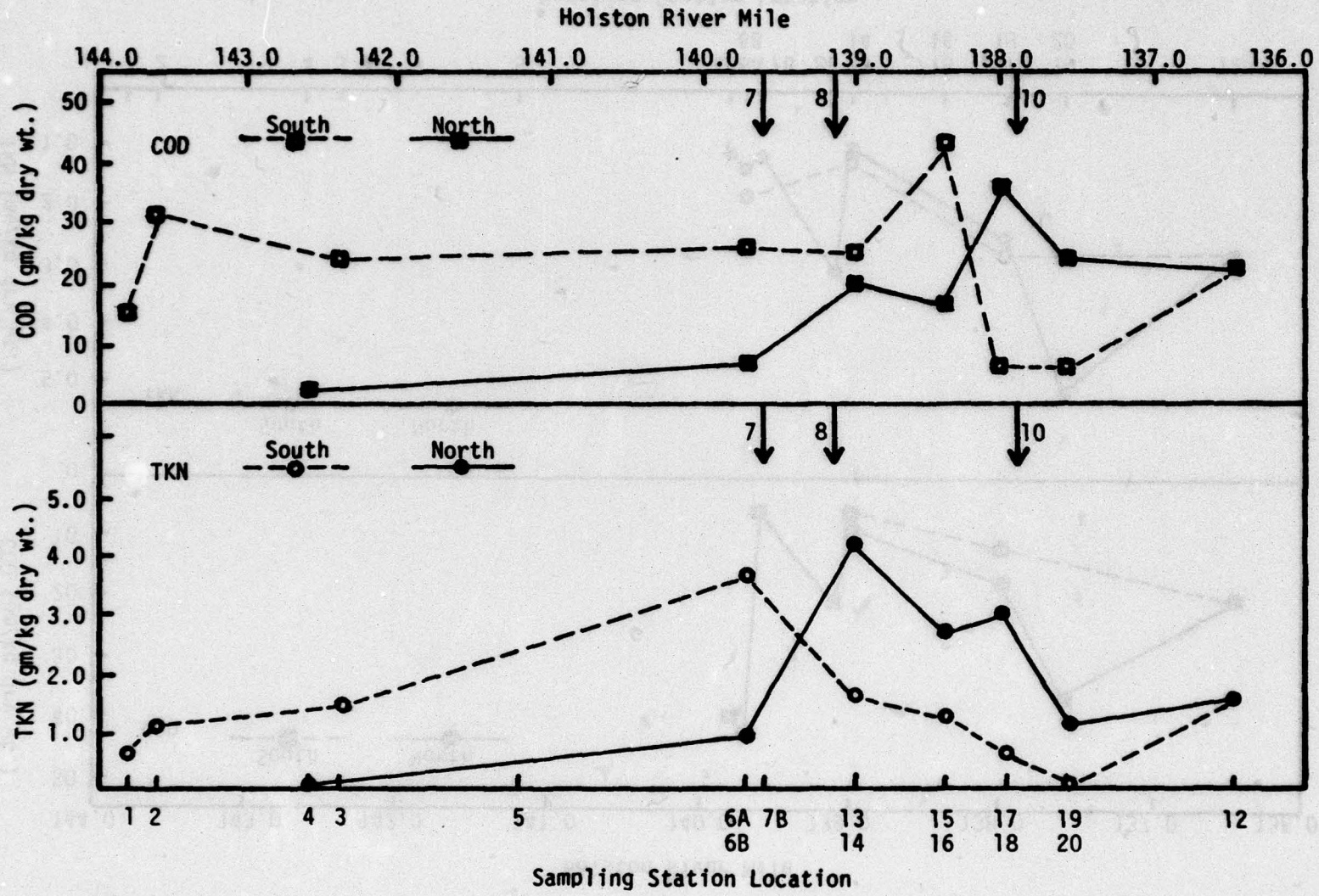


FIGURE 29. DISTRIBUTION OF MEAN COD AND TKN IN HOLSTON RIVER SEDIMENTS, JUNE, 1975.

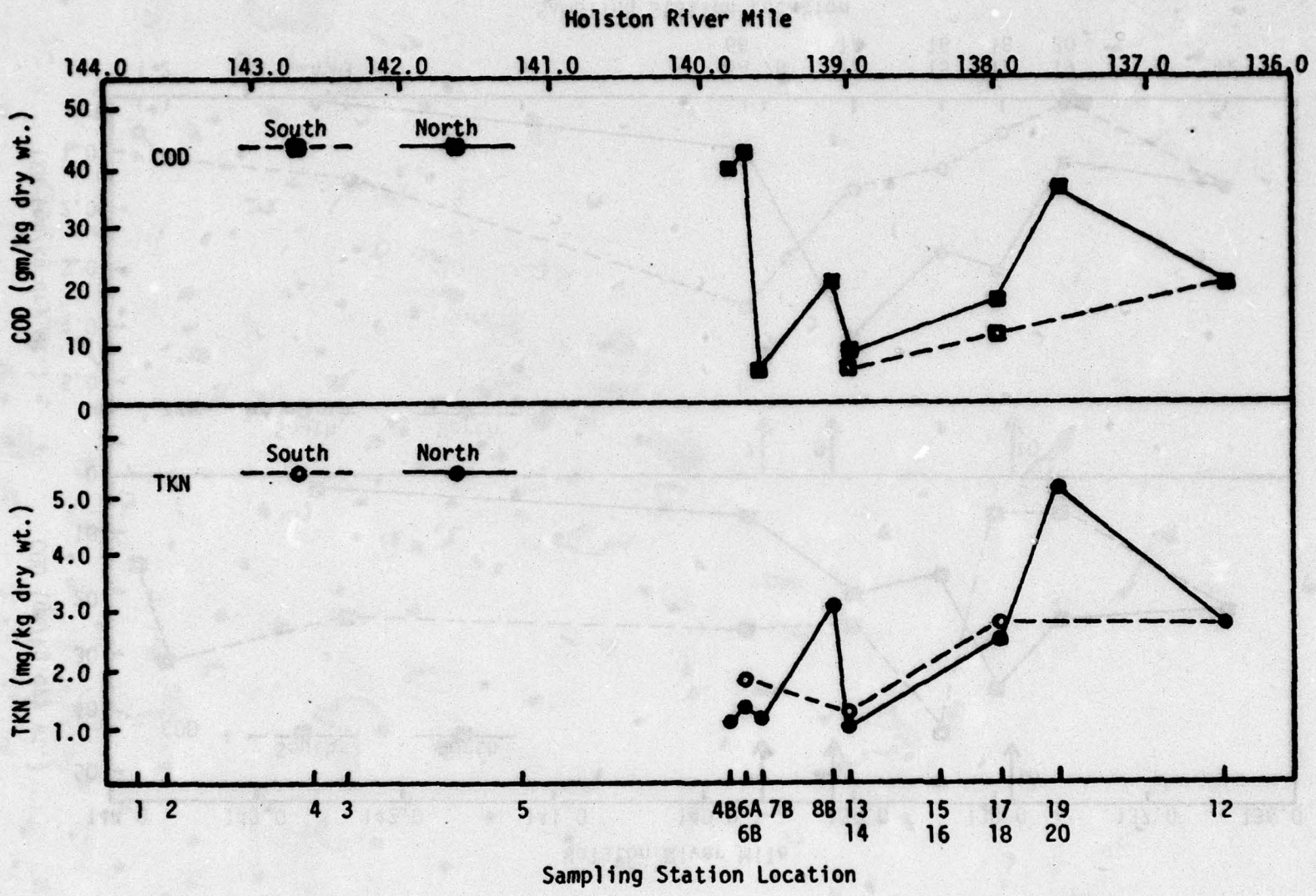


FIGURE 30. DISTRIBUTION OF MEAN COD AND TKN IN HOLSTON RIVER SEDIMENTS, AUGUST 1975

is known about the fate and distribution of such materials although several in-depth studies have been conducted. Iskandar and Keeney (1974), Holmes, et al. (1974), and Harris (1974) found that redistribution of metals between sediments and over-lying waters in lakes and estuaries occurs seasonally, paralleling variations in pH, D.O., temperature, etc. In river systems precipitation of insoluble species and scavenging of metals by sorption to suspended particulates are two main pathways for river sediment enrichment. Appendix A-7 tabulates the concentrations found in the Holston sediments in June and August, 1975. As expected, iron and manganese ranged an order of magnitude higher than the other metals. No trends associated with HAAP discharges were apparent. Ranges of the various species are tabulated below:

Element	Concentration Range mg/kg dry weight
Fe	890 - 36,000
Mn	180 - 2,500
Cd	Below Detection
Cr^{+6}	14 - 110
Cu	2 - 650
Hg	<0.1 - 6.3
Ni	7 - 49
Pb	8 - 990
Zn	33 - 1,000

High manganese and the consistently detectable lead are likely related to Tennessee Eastman discharges. Iskandar and Keeney (1974) were able to show distribution of copper, lead, and zinc in Wisconsin lake sediments related to cultural activities on the watersheds. Ranges for copper were 0 - 400 mg/kg; lead, 5 - 160 and zinc 10 - 200, roughly similar to those found in the Holston sediments. The Holston data also correspond to levels in estuarine sediments (WAR, Inc., 1975). Data for lead, zinc, chromium, copper, and nickel are similar to those of Wapora, Inc.(1975) and the EPA (1972, 1973a). STORET data covering the period 1966 - 1970 showed little mercury in the sediment. Concentrations ranged from 0.2 - 2.7 mg/kg. The high value was observed in the North Fork. Mercury associated with the discharge from a chlorine manufacturing plant on the North Fork was the probable source for contaminated sediments in the study reach. The plant is no longer operating and the mercury in the WAR samples originated from sediment transported down the North Fork. Therefore, the sediments in this reach should recover in the near future from this environmental stress.

The environmental significance of metal concentrations measured by elemental analysis is unclear. Elutriation (Keeley and Engler, 1974) and ammonium acetate extraction measure the amounts leachable from the sediment interstitual water. The relative amounts of the various fractions available or which can act on benthic organisms are undefined. Little evidence exists (WAR, 1975, Keeney and Iskandar, 1974) for biotic effects at the levels reported in this study. HAAP discharges are unlikely to be responsible for significant metal contamination of Holston River sediments.

Munitions. Table 5 presents munitions residues found in samples of sediment from selected stations in the Holston River. No RDX or HMX

TABLE 5

MUNITIONS RESIDUES IN HOLSTON RIVER SEDIMENTS, 1975

Station	TNT (mg/kg Dry Wt.)	
	June	August
6A	<0.1, <0.1, <0.1	<0.1
6B	<0.1	<0.1
7B		<0.1
8B		<0.1
12	2.6	
13	-	<0.1
14	0.2	<0.1
15	<0.1	
18	2.0	3.4
20	4.2	2.5

above 0.2 mg/kg was detected. Trinitrotoluene residues were found, however, in generally increasing concentrations downstream at Stations 14, 18, and 20 along the north bank. Significant residues were also present in the June sample at Station 12 downstream. No south bank sediment contained detectable residues. This pattern is one which would be expected based on the mixing characteristics of the river and the sparing solubility of TNT in water. Scour and redistribution of sediments might be expected to prevent build-up of high concentrations such as the ~600 mg/kg observed at one station at Iowa Army Ammunition Plant (IAAP); (Weitzel, et al., 1975). Apparently, RDX either does not deposit or precipitates in a region where other sediment does not collect, thus being scattered downriver. RDX spikes added to test samples were quantitatively recovered indicating the absence rather than indetectability of this residue in Holston sediments. Wapora, Inc (1975) were unable to detect TNT related residues with detection limits of >10 mg/kg for TNT or 2,4-DNT, and >5 mg/kg for 2,6-DNT.

The TNT concentrations reported may considerably underestimate the actual TNT related biotoxic residues present. Microbial breakdown occurs stepwise giving rise to dinitrated amines and hydroxyl amines such as 4 amino-2,6-dinitrotoluene. Resistance of aromatic rings to attack is measured by increased numbers of nitro-radicals (McCormick, 1974) and toxicity of intermediate breakdown products may be as great or greater than the parent compound. Weitzel, et al. (1975) were able to characterize a major TNT breakdown product in sediment at IAAP as a monohydroxylamino-dintrotoluene which exhibited comparable biotoxic properties with TNT and further found concentrations of this daughter in sediments at times equal to or greater than corresponding TNT concentrations.

PERIPHYTON

Introduction

The periphyton or "Aufwuchs" community is an assemblage of attached microorganisms (primarily algae) growing on the free surfaces of submerged substrates forming a slimy green or brown coating. The attached periphyton community consists of an assemblage of both autotrophic (i.e. diatoms and filamentous algae) and heterotrophic (bacteria, protozoa, rotifers, etc.) organisms.

Odum (1956) reports that under clear, clean water conditions, the algal component of the periphyton community can develop a large standing crop (e.g. 100 gm dry wt/m^2, Silver Springs, Florida) and therefore represents an important food source for a wide variety of riverine organisms. As levels of organic pollution increase, algae are replaced by filamentous bacteria and other non-chlorophyllous "consumer-type" organisms (such as Sphaerotilus) resulting in significant increases in biomass-chlorophyll ratios and the establishment of a heterotrophic periphyton community (Weber and McFarland, 1969).

Major factors which limit or control periphyton growth in riverine environments are light, turbidity levels, temperature, current, nutrient, and substrate availability. Current provides a nutrient supply and carries away dead organic matter. Adequate light penetration is essential for periphytic algal growth. Turbidity affects periphyton production by limiting light penetration.

Temperature plays an important role in regulating periphyton algal flora as optimum growth occurs between 15 and 25°C. Increases in ambient river temperatures encourage the growth of Chlorophyceae, especially Cladophora, with the Cyanophyceae reaching maximum development in warm waters. Diatoms, on the other hand, tend to dominate during periods of low temperature. Seasonal light conditions along with temperature also regulate periphyton populations. This interaction may mask the direct effects of temperature.

Periphyton growth is also dependent upon substrate stability. Shifting materials such as sand or small pebbles provide poor habitat for periphyton in contrast to rocks or rooted aquatic vegetation (Hynes, 1966). The periphyton community lends itself well to biological investigations of water pollution. These organisms remain at fixed locations and are sensitive to changing environmental conditions. Their populations and biomass are relatively easy to quantify using standard laboratory procedures and are adaptable to a variety of statistical analyses. When natural limiting factors do not exert overriding effects, periphyton are excellent indicators of stream nutrient status.

A detailed study of the Holston River periphyton community was conducted during the summer of 1975 in the vicinity of the Holston Army Ammunition Plant, Kingsport, Tennessee. The purpose of this investigation was to investigate and report the effects of RDX and other munitions-related compounds upon the Holston River periphyton flora.

Previous studies of the effects of munitions related compounds upon natural periphyton communities have varied widely. For example, Wapora, Inc. (1975) surveying New River, Virginia and the Obion River in Tennessee was unable to correlate periphyton community structure with pollutant loading. Field studies by Water and Air Research (1975) at the Longhorn, Texas and Louisiana Army Ammunition Plants indicated no significant effects on stream periphyton due to munitions waste effluents. However, results of Battelle Columbus Laboratories (1975) on three munitions facilities (Badger Army Ammunition Plant, Baraboo, Wisconsin; Joliet Army Ammunition Plant, Joliet, Illinois; and Lake City Ammunition Plant, near Kansas City, Missouri) reported observable effects of munitions waste discharges on the periphyton community. Wapora, Inc.'s (1975) study of Lake Chickamauga, Chattanooga, Tennessee, reported differences in periphyton community structure in the area of Waconda Bay in the vicinity of Volunteer Army Ammunition Plant waste discharge. Weitzel, et al. (1975) observed shifts in periphyton species diversity corresponding to variations in nutrient levels and TNT concentrations in the streams adjacent to the Iowa Army Ammunition Plant.

Periphyton studies conducted on the Holston River in the area of the Holston Army Ammunition Plant have indicated various degrees of environmental stress due to the discharge of ammunition wastes. Wapora's (1975) report on the effects of munition wastes on the periphyton community indicated that the percentage of the populations present as diatoms was considerably lower on the north bank as opposed to the other shore.

The U.S. Army Environmental Hygiene Agency (1973) reported that the Holston River was "too polluted to allow a meaningful assessment of environmental impact attributable to Area B (HAAP production area) effluents." However, diversity indices showed no discernible effects from the nitric acid production wastes or from effluent production lines (2, 3, 4, and 5). Water quality and periphyton diversity indices increased, however, downstream from the confluence of the Holston River and Arnott Branch due to (1) reduction in organic load due to dilution from Arnott Branch; and (2) reoxygenation of the water caused by riffle areas downstream.

Studies in progress (Water and Air Research, Inc., 1975-1976)[1] on Lake Chickamauga, Tennessee report impacts on periphyton community structure and biomass due to TNT, nitrite, and other associated munitions waste. Alterations in community structure were observable in waters containing 100 ppb of TNT. No effects were seen below this concentration.

Methods

Both natural and artificial substrate periphyton communities were studied during June-July and August-September, 1975. Due to a lack of comparable natural substrates from which to sample, periphyton collections made with artificial substrates probably give the more reliable station to station comparison. Standard microscope glass slides were placed in periphyton

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[1] Draft in preparation for Army Medical Research and Development Command.

samplers one inch below the water surface at eight selected HAAP locations (Figures 2 and 3) according to the procedures outlined in Standard Methods for the Examination of Water and Wastewater 13th Edition (APHA, 1971) and Biological Field and Laboratory Methods for Measuring the Quality of Surface Water and Effluents (EPA, 1973). Table 6 presents a description of each biological station.

The artificial substrates were incubated for 2- and 4-week intervals during June-July and August-September, 1975 (for a total of four surveys). Due to unusual flooding conditions during the August-September 4-week sampling period, a number of samplers were swept away leaving only one series of glass slides within the impact area. As a result, analyses of these samples were omitted.

At the end of each incubation period, five replicate slides were removed randomly from each sampler for the following laboratory analyses:

- Filamentous organisms
- Organic biomass (ash-free dry weight) and chlorophyll a for the determination of an Autotrophic Index and net primary production
- Diatom community structure

Filamentous Organisms. Attempts were made to examine quantitatively the filamentous algae component of the Holston River periphyton community. Artificial substrates (glass slides) were incubated in the river for four weeks during June 11-July 10, 1975. At the end of the incubation period the periphyton slides were removed and preserved in five percent Formalin in a light excluding sample box. In the laboratory the slides were scraped and preserved in labeled sample bottles containing 50 ml of a 5 percent Formalin solution. Filamentous algae were identified by the Utermohl (1958) sedimentation technique utilizing a 50 ml plankton counting chamber and a Zeiss inverted D microscope. Identifications were carried to species level where possible utilizing the following standard references: Drouet (1968); Prescott (1962); and Desikachary (1956).

Organic Biomass and Chlorophyll a. Growth of periphyton on artificial substrates was measured as organic biomass (ash-free dry weight) and chlorophyll a (corrected for phaeopigments) after 4-week incubation. Standard procedures were used for asssesing biomass and chlorophyll a levels as outlined below. Primary production estimates were made using chlorophyll a as indicated. These parameters were used to assess the standing crop of both the autotrophic and heterotrophic components of the attached community and to characterize summer production levels in the Holston River.

Periphyton communities in unpolluted waters tend to be dominated by algae, especially diatoms. The organic weight, or biomass to chlorophyll ratio, in such communities approaches that of an algal culture, i.e. 50 - 100. Organic pollution, particularly, causes an increase in the ratio due to increase in the heterotrophic component (bacteria such as Sphaerotilus natans, fungi, and protozoa) while toxic effects may decrease total mass of either heterotrophic component, autotrophic component, or both.

TABLE 6

DESCRIPTION OF HAAP BIOLOGICAL
SAMPLING STATIONS JUNE-SEPTEMBER, 1975

Station No.	River Mile*	Holston River Stations Description
1	143.8	Four-tenths of a mile into the sluice tributary to the South Fork at Long Island. Bottom mud. Floating algal mats on mud banks, intermittent Potomogeton crispus beds.
2	143.6	One and four-tenths miles up the South Fork along the North Bank, 18 yards upstream of the outfall at Edwards Bridge.
4	142.6	Four-tenths of a mile up into the North Fork. Rapid shallow wide river, bottom large rocks.
3	142.4	Two hundred yards upstream of the confluence with the North Fork along the north bank.
4B	139.8	North bank of Holston River approximately 350 yards upstream of first HAAP munitions waste outfall; Bottom - fine sand.
6B (E)**	139.7	North bank about 180 yards upstream from the first HAAP munitions waste outfall; Bottom - clay, coarse sand and gravel, small amount of leaf litter.
6A (EE)**	139.6	South bank, upstream from the first HAAP munitions waste outfall; Bottom - rocks, clay and sand, with leaf litter. Station 6A was located in a luxuriant grass bed comprised of Potamogeton pectinatus, P. nodosus, P. crispus, and Vallisneria americana.

TABLE 6 (Continued)

Station No.	River Mile	Holston River Stations Description
7	139.6	Outfall pipe discharge, production lines 6, 7, 8.
7B (F)**	139.6	North bank, 50 yards downstream of first HAAP munitions outfall ditch; Bottom - anaerobic sediments, fine sand and clay, leaf litter and sticks. Heavy growths of sewage bacterium Sphaerotilus natans.
8	139.1	North of outfall ditch, production lines 2, 3, 4, and 5.
8B and $8B_1$ (H)**	139.1	8B - North bank immediately downstream from second HAAP munitions waste outfall. $8B_1$ - ten yards downstream from Station 8B; Bottom - anaerobic sediments, fine sand and clay, leaf litter, sticks. Heavy growths of Sphaerotilus, and blue-green algae on exposed river banks.
14	139.0	North bank, 200 yards downstream from HAAP munitions outfalls, north of island; Bottom - black clay and organic matter, leaf litter, anaerobic sediments. Heavy growths of Sphaerotilus.
17	138.0	South bank, 1.1 miles downstream from the two HAAP munitions waste outfalls; Bottom - clay, leaf litter, sticks and branches. Station 17 located in extensive grass beds of Potamogeton pectinatus, P. nodosus, P. crispus, and Vallisneria americana.
18 (I)**	138.0	North bank, 1.1 miles downstream from the two HAAP munitions waste outfalls; Bottom - clay, mud, leaf litter, Vallisneria americana, and Potamogeton crispus present on river bank in low densities.

TABLE 6 (Continued)

Station No.	River Mile	Holston River Stations Description
10	137.95	Arnott Branch receiving wastes from the nitric acid area. Bottom type, large rocks and debris.
20 (J)**	137.6	North bank, 0.3 miles downstream from Arnott Branch; Bottom - shale, sand, and mud.
12 (K)**	136.5	Mid-river, 1.4 miles downstream from Arnott Branch; Bottom - sticks, leaf litter, and organic detritus.

*U.S. Geological Survey River Miles.
**Corresponding station studied by Smock and Stoneburner (1973).

The levels of periphyton biomass, therefore, serve as an overall index of biological activity in the producer and decomposer compartments as influenced by environmental conditions. Weber and McFarland (1969) have examined artificial substrate data from a number of environments, both polluted and unpolluted, and arrived at an "Autotrophic Ratio" of 100 or less as being indicative of clean water conditions.

Five replicate slides were rehydrated for 15 minutes for biomass determination with accumulated material scraped from the slide and resuspended in 50 ml of distilled water. Twenty-five ml was preserved with Formalin for species identification and quantification; the remaining half of the suspension was collected using a tared fired glass filter (Gelman, GFA), the ash free dry weight determined (Standard Methods, 1971), and converted to grams of organic matter per square meter as ash free dry weight.

$$gm/m^2 = \frac{(2)\ (gms\ Ash\ Free\ Dry\ Weight)}{0.00375\ m^2/slide}$$

Net production based on biomass accumulation was calculated by converting organic biomass to equivalent carbon[1] then dividing by the incubation period.

Five replicate slides were collected for chlorophyll *a*, placed in 50 ml of 90 percent acetone - 10 percent saturated $MgCO_3$ solution and immediately stored in the dark at -20°C in dry ice. Prior to analysis, slides were scraped and the acetone suspension ground 30 seconds at 500 rpm in a Potter type tissue homogenizer.

Chlorophyll *a*, corrected for phaeophytin, was determined fluorometrically after the methods of Yentsch and Menzel (1963), Holm-Hanson, et al. (1965), Lorenzen (1967), and Moss (1968), using a Turner Design Model 10 fluorometer. The reference solution used was spinach chlorophyll standard[2] calibrated by spectrophotometric chlorophyll analysis. Chlorophyll breakdown products, phaeopigments, cause a positive interference. Acidification of chlorophyll *a* converts it quantitatively to phaeophytin. Reading the fluorescence before and after adding one drop of 1N HCl to the sample cuvette allows calculation of an acid factor related to the interference. Chlorophyll *a* was calculated as follows:

$$\text{Chlorophyll } a \text{ (weight/area)} = \frac{(F)(r)(Ru-Ra)(\text{Vol. Extract})}{(r-1)(\text{substrate area})}$$

where: Ru = fluorometer reading before acidification
Ra = fluorometer reading after acidification

$$r = \frac{Ru\ std}{Ra\ std}$$

$$F = \left[\frac{Ca}{Ru\ std}\right]\left[\frac{\text{dilution of standard fluorometer}}{\text{dilution of standard spectrophotometer}}\right]$$

Ca = Actual chlorophyll *a* concentration in standard determined spectrophotometrically.

[1] Gram organic matter (2) (grams Carbon), Odum, 1971.
[2] Sigma Chemicals, St. Louis, Missouri, Product #C5753.

Net primary productivity based on chlorophyll a accumulation on slides was computed for the 2- and 4-week incubation in terms of grams carbon per square meter based on a chlorophyll to plant carbon ratio of 60 (Parson and Strickland, 1968).

$$\frac{[\text{Chlorophyll } a\ (gm/m^2)]\ [60]}{\text{Days Incubated}} = \text{Net Primary Production } (gm\ C/m^2/day)$$

Autotrophic Index. The autotrophic index (Weber and McFarland, 1969) indicates the relative composition of the developing periphyton community. This ratio is expressed as:

$$\frac{\text{Organic Biomass } (gm/m^2)}{\text{Chlorophyll } a\ (gm/m^2)}$$

and has been used to indicate organic pollution and effluent toxicities. The numerical value of this index increases with an increase in non-algal or heterotrophic biomass and decreases with increasing algal biomass. Systems receiving inputs of organic materials will show elevated heterotrophic biomass and thus a higher index due to proliferation of attached bacteria and protozoa. Nutrient enriched or autotroph dominated systems on the other hand will approach autotrophic indices of 100-500 (Weber, 1973a) reflecting the ratio of chlorophyll to plant carbon. An autotrophic index greater than 100 indicates organic pollution, less than 100 "clean water" conditions (Weber, 1973b).

Diatom Community Structure. In terms of cost effectiveness and information content, the diatom (Bacillariophyceae) component of the periphyton community represents the most important group of algae studies in general water quality monitoring surveys. Cairns, et al. (1972) report that other groups of algae (e.g. Cyanophyceae and Chlorophyceae) are sensitive to pollution stresses but the difficulty and high cost of identifying them to the species level by axenic culturing methods (Archibald and Bold, 1970) precludes their use in most field monitoring studies.

Diatom cell density estimates (cells/mm^2) were determined by the following methods. Periphytic diatoms were collected from artificial substrates (glass slides) after 2- and 4-week incubation periods and were air dried in the field in individual labeled plastic containers. In the laboratory, each slide (total area of 3,871 mm^2) was scraped with a razor blade into 50 ml of distilled water. Diatom frustules were "cleaned" for microscopic examination by pipetting 10 ml of the algal suspension into a labeled beaker containing 10 ml of hydrogen peroxide. This solution was gently heated to 93°C (200°F), and approximately 60 mg of potassium dichromate oxidized the organic material within the diatom frustule. The solution was cooled and centrifuged for 15 minutes, decanted and brought to a volume of 25 ml (2.5 times the original volume of 10 ml). The 2.5 fold dilution was necessary so that permanent slides would have a distribution of 10-15 organisms per field when magnified 1250 diameters.

Permanent diatom mounts were prepared by pipetting 0.4 ml of the "cleaned" material onto a 18 x 18 m coverslip (324 mm^2) and allowing the

sample to dry at 65°C (150°F) on a laboratory hot plate. The dried coverslip was placed on a microscope slide containing several drops of HYRAX mounting medium (refractive index, 1.71) and the slide was gently heated to drive off the toluene solvent. Under an oil immersion lens (Zeiss microscope, 1250X) diatoms were identified and enumerated to the species level where possible utilizing the following standard taxonomic references: Hustedt, 1930, 1962; Cleve-Euler, 1952; Schmidt et al., 1987-1959; Huber-Pestalozzi, 1942; Hustedt, 1930, and Patrick and Reimer, 1966.

Diatom cell densities (cells/mm^2) were estimated by performing 30 field counts while scanning the slide from left to right (15 field counts) and from top to bottom (15 field counts). Each microscope field represented an area of 0.038 mm^2, with a total area examined of 1.14 mm^2 (0.038 mm^2 x 30 field counts). Cell densities were estimated using the following formula:

$$\text{Cells/mm}^2 = \frac{\text{Diatom Counts} \times \frac{\text{Total Area of Coverslip (324 mm}^2\text{)}}{\text{Total Area Examined (1.14 mm}^2\text{)}} \times \frac{\text{Original Volume of Periphyton Suspension (50 ml)}}{\text{Volume of Sample Dried on Coverslip (0.4 ml)}} \times \text{Dilution Factor (2.5)}}{\text{Original Surface Area of Slide (3,871 mm}^2\text{)}}$$

In an effort to compare diatom populations from station to station, cell density estimates were used to calculate community indices such as: the Shannon-Weaver Species Diversity Index (H), (Shannon and Weaver, 1949; Margalef, 1968) to the base e; and the Shannon Evenness Index, J (Pielou, 1966). In addition, stations were compared by measuring the degrees of similarity between species associations at different stations utilizing Sorensen's (1948) coefficient of similarity, and the Pinkham-Pearson (1974) Index of Biotic Similarity (see Computational Methods for detailed explanations of the above indices).

Collections of periphytic algae were also made from natural substrate materials. In the Holston River, natural substrates such as rock, submerged logs, or aquatic vegetation were not readily available at each station for the collection of periphyton. As an alternative measure, short cores were made of extensive blue-green algal mats occurring on the north bank of the Holston River during June, 1975. Mats were uniformly sampled utilizing a simple PVC pipe coring device (3.0 cm diameter). Filamentous algae were preserved in 5 percent Formalin solution. Since only the diatom component of the mat was to be considered, the samples were oxidized utilizing the hydrogen peroxide - potassium dichromate "cleaning" procedure previously described for processing artificial substrate periphyton samples. No attempt was made to quantify cell densities per mm^2 as the surface area of each filamentous algal mat was unknown. Approximately 500 diatom frustules were counted and identified per sample in an effort to determine diatom community structure on a qualitative basis.

Presentation of Data

Seven species of filamentous algae and 114 species of diatoms representing 31 genera were recorded from the HAAP artificial substrate sampling stations. Tables 7-10 show all diatom and filamentous algae species recorded during the study period including cell densities and distribution patterns among stations.

In addition to artificial substrates, a selected number of natural substrates was also analyzed for diatom community structure. Table 11 presents a list of the diatom species recorded from the Holston River natural substrates. Two other biological parameters, periphyton biomass and chlorophyll a, were quantitatively monitored for the determination of an autotrophic index and net primary production.

Filamentous Organisms. Attempts to quantify periphytic filamentous organisms on a per unit area basis by the use of a number of standard counting techniques and apparatus (i.e. Sedgewick-Rafter counting cell, inverted microscopic counting cell) were generally unsuccessful. Most filamentous species occurred as clumped material with the ends of filaments firmly embedded within detrital particles or occurring as part of the large thallus of the green algae, Stigeoclonium tenue. As a result, filamentous organisms were qualitatively examined on the basis of presence-absence criteria. Table 10 provides a list of the most common filamentous species encountered at each of the stations.

With the exception of Station 12, the most abundant filamentous organism observed at each station location was the pollution resistant green algae, Stigeoclonium tenue. At a number of stations this filamentous species literally covered the entire slide with its prostrate thallus and irregularly-branching filaments. Westlake and Edwards (1956) report S. tenue as a characteristic algae of waters rich in nutrient salts, especially in the presence of an abundant supply of nitrates. Blum (1957) identified S. tenue as a summer dominant in association with the sewage bacterium Sphaerotilus natans, occurring below organic pollution outfalls in the Saline River, Michigan. Butcher's (1947) studies of European river systems noted the replacement of a wide variety of normal eutrophic river algae dominated by Cocconeis, Ulvella, and Chamaesiphon species by the pollution tolerant species Stigeoclonium tenue, Gomphonema parvulum, and Nitzschia palea.

Large populations of Stigeoclonium dominated the algal flora at both the upstream reference stations (4B,6A,6B) and the impact stations 7B through 20. S. tenue populations were greatly reduced at Station 12 and may indicate a partial recovery from upstream pollution. The presence of this pollution "indicator species" at both the reference and impact stations suggests that the Holston River supports a relatively large population of pollution resistant filamentous algae characteristic of nutrient enriched waters. This statement is supported by the chemical data collected during the June periphyton incubation period where nutrients averaged about 0.8 mg NO_3-N/l, 0.1 mg Total-P/l, and 9.0 mg TOC/l at the reference stations 4B, 6B, and 6A.

The high levels of nutrients and associated poor water quality in this stretch of the Holston River may be attributable to a number of upstream point source effluents contributing heavy loadings of BOD and TKN. Recent

TABLE 7

DIATOM TAXA OBSERVED ON HAAP ARTIFICAL SUBSTRATES.
JUNE 2-WEEK INCUBATION (CELLS/MM^2)
Counts Based on Pooled Replicates

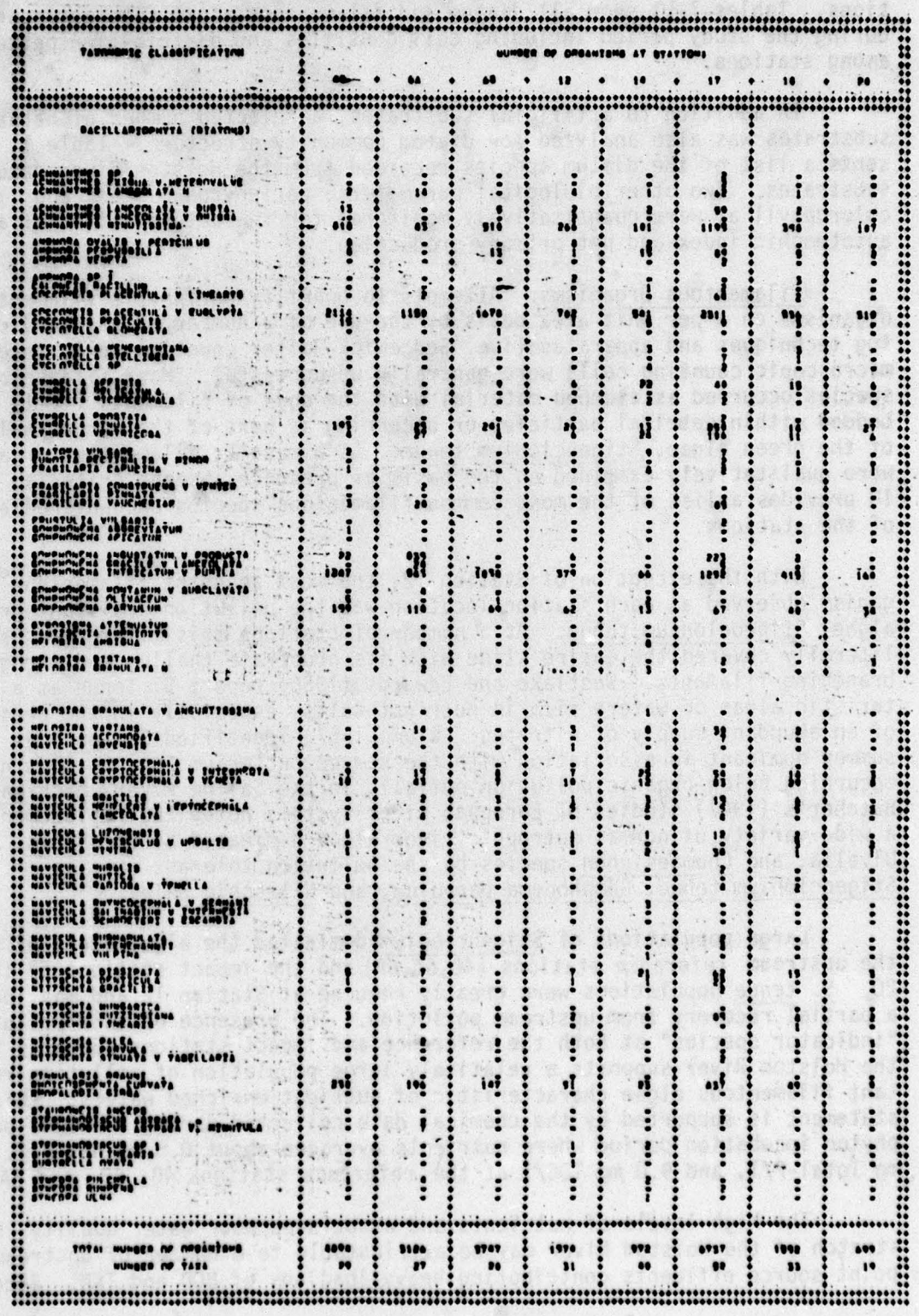

TABLE 8

DIATOM TAXA OBSERVED ON HAAP ARTIFICIAL SUBSTRATES. JUNE 4-WEEK INCUBATION (CELLS/MM^2)

Counts Based on Pooled Replicates

TAXONOMIC CLASSIFICATION	NUMBER OF ORGANISMS AT STATIONS							
	4B	6A	6B	12	14	17	18	20
BACILLARIOPHYTA (DIATOMS)								
ACHNANTHES SP A	30	82	21	29	201	204	140	82
ACHNANTHES LANCEOLATA H	29	22	-	15	30	109	8	-
ACHNANTHES LANCEOLATA V DUBIA	22	-	21	22	29	114	18	-
ACHNANTHES MINUTISSIMA	6310	625	4114	3043	2803	9113	2170	800
ACHNANTHES NOLLII	-	15	9	-	-	4	-	-
AMPHORA OVALIS V PEDICULUS	83	-	30	70	97	220	30	7
AMPHORA OVALIS V LIBYCA	-	-	-	-	7	-	-	-
AMPHORA PERPUSILLA	15	-	9	-	7	87	-	-
AMPHORA SP 1	-	-	-	-	-	9	-	-
ANOMOEONEIS VITREA	-	-	-	-	-	4	-	-
BIDDULPHIA LAEVIS	-	-	-	-	-	4	12	-
CALONEIS BACILLUM	-	15	4	7	22	31	6	-
COCCONEIS PLACENTULA V LINEATA	-	15	8	-	7	30	-	-
COCCONEIS PLACENTULA V EUGLYPTA	8030	2421	3045	1005	1412	2009	806	1045
COCCONEIS PEDICULUS	14	22	8	15	78	8	13	-
CYCLOTELLA MENEGHINIANA	7	-	13	16	29	13	20	-
CYCLOTELLA STELLIGERA	14	7	26	22	67	80	43	7
CYMBELLA AFFINIS	14	22	4	22	30	13	20	-
CYMBELLA DELICATULA	-	-	-	-	-	4	-	-
CYMBELLA SINUATA	200	30	200	190	90	201	83	-
CYMBELLA VENTRICOSA	14	44	20	14	90	70	44	7
CYMBELLA PROSTRATA	7	-	-	-	-	13	-	-
CYMBELLA MICROCEPHALA	-	15	4	-	-	4	4	7
CYMBELLA TUMIDA	-	-	4	-	-	-	-	-
DIATOMA VULGARE	-	-	4	-	14	-	8	-
FRUSTULIA VULGARIS	-	-	4	-	-	4	-	-
FRAGILARIA CAPUCINA	-	15	8	16	22	30	8	16
FRAGILARIA CONSTRUENS V VENTER	-	-	-	-	-	13	-	-
FRAGILARIA CROTONENSIS	-	-	-	-	7	-	-	-
FRAGILARIA HARRISONII	-	-	-	7	-	-	-	-
FRAGILARIA PINNATA	-	-	-	-	-	-	8	-
FRAGILARIA VAUCHERIAE	67	90	40	7	114	100	103	16
GOMPHONEMA ACUMINATUM V MONTANUM	-	7	-	-	-	-	-	-
GOMPHONEMA ANGUSTATUM V PRODUCTA	21	900	8	45	67	200	21	-
GOMPHONEMA GRACILE V LANCEOLATA	-	7	-	-	-	4	-	-
GOMPHONEMA INTRICATUM V PUMILA	2030	902	1966	2001	616	3017	1309	1095
GOMPHONEMA OLIVACEUM	-	7	-	-	16	-	4	-
GOMPHONEMA PARVULUM	67	90	94	101	213	199	135	180
MELOSIRA AMBIGUA	37	22	8	-	7	30	30	-
MELOSIRA DISTANS	-	14	-	-	29	22	13	-
MELOSIRA GRANULATA H	14	15	9	-	22	-	30	-
MELOSIRA GRANULATA V ANGUSTISSIMA	-	-	-	22	-	-	-	10
MELOSIRA VARIANS	37	60	22	45	37	221	94	22
MERIDION CIRCULARE	-	-	-	-	7	-	-	-
NAVICULA ACCOMODATA	-	-	4	-	-	-	-	-
NAVICULA CONTENTA V BICEPS	-	-	-	-	-	-	4	-
NAVICULA CRYPTOCEPHALA V INTERMEDIA	45	83	22	45	67	309	72	7
NAVICULA CRYPTOCEPHALA V VENETA	60	114	62	120	113	302	170	30
NAVICULA GRACILIS	29	29	8	-	7	42	30	-
NAVICULA INGRATA	-	-	-	-	-	4	-	-
NAVICULA LANCEOLATA	-	-	-	7	7	8	4	-
NAVICULA LUZONENSIS	-	7	-	-	-	-	-	-
NAVICULA MENISCULUS V UPSALIENSIS	-	-	-	-	-	4	-	7
NAVICULA MINIMA	15	29	16	45	29	800	83	30
NAVICULA MUTICA	-	-	-	7	7	10	-	-
NAVICULA PYGMAEA	7	-	-	-	-	4	-	-
NAVICULA RADIOSA V TENELLA	-	7	4	-	-	8	-	7
NAVICULA RHYNCHOCEPHALA	-	-	-	29	-	-	-	-
NAVICULA SYMMETRICA	22	7	21	7	22	40	20	-
NAVICULA SP 1	-	7	-	7	15	8	-	-
NAVICULA SP D	-	-	-	7	-	-	-	-
NITZSCHIA ACICULARIS	-	-	-	-	-	-	4	-
NITZSCHIA AMPHIBIA	-	-	-	-	-	8	-	-
NITZSCHIA ANGUSTATA	-	-	-	7	-	-	-	-
NITZSCHIA DISSIPATA	29	909	40	15	67	44	94	15
NITZSCHIA DENTICULA	22	-	8	-	7	42	12	-
NITZSCHIA GRACILIS	-	-	-	7	-	4	-	-
NITZSCHIA KUTZINGIANA	7	7	13	37	22	614	8	7
NITZSCHIA IGNORATA	-	-	4	-	-	-	4	-
NITZSCHIA LINEARIS	-	15	4	-	14	8	-	-
NITZSCHIA MICROCEPHALA	-	-	-	-	15	31	-	-
NITZSCHIA PALEA	30	-	-	7	29	44	40	-
NITZSCHIA RECTA	-	-	-	-	-	-	4	-
NITZSCHIA SP 1	14	7	26	-	7	90	30	-
PINNULARIA BRAUNII	-	-	-	-	-	-	4	-
RHOICOSPHENIA CURVATA	602	900	209	343	143	891	80	30
STEPHANODISCUS ASTRAEA	-	15	9	-	37	13	17	-
STEPHANODISCUS SP 1	51	64	43	70	219	200	140	60
SURIRELLA LINEARIS	-	-	-	-	-	4	12	-
SURIRELLA OVATA	-	-	8	-	-	13	4	-
SYNEDRA PARASITICA	-	-	-	7	-	4	-	-
SYNEDRA PULCHELLA	7	-	-	-	7	-	-	-
SYNEDRA DELICATISSIMA	-	-	-	-	15	4	4	-
SYNEDRA RUMPENS	-	-	-	-	-	4	-	-
SYNEDRA ULNA	-	-	-	-	22	4	-	7
TABELLARIA FENESTRATA	-	-	-	-	7	-	-	-
TOTAL NUMBER OF ORGANISMS	15060	7300	10703	12000	6710	20730	6130	3900
NUMBER OF TAXA	30	40	44	30	51	63	60	23

TABLE 9

DIATOM TAXA OBSERVED ON HAAP ARTIFICIAL SUBSTRATES.
AUGUST 2-WEEK INCUBATION (CELLS/MM^2)

Counts Based on Pooled Replicates

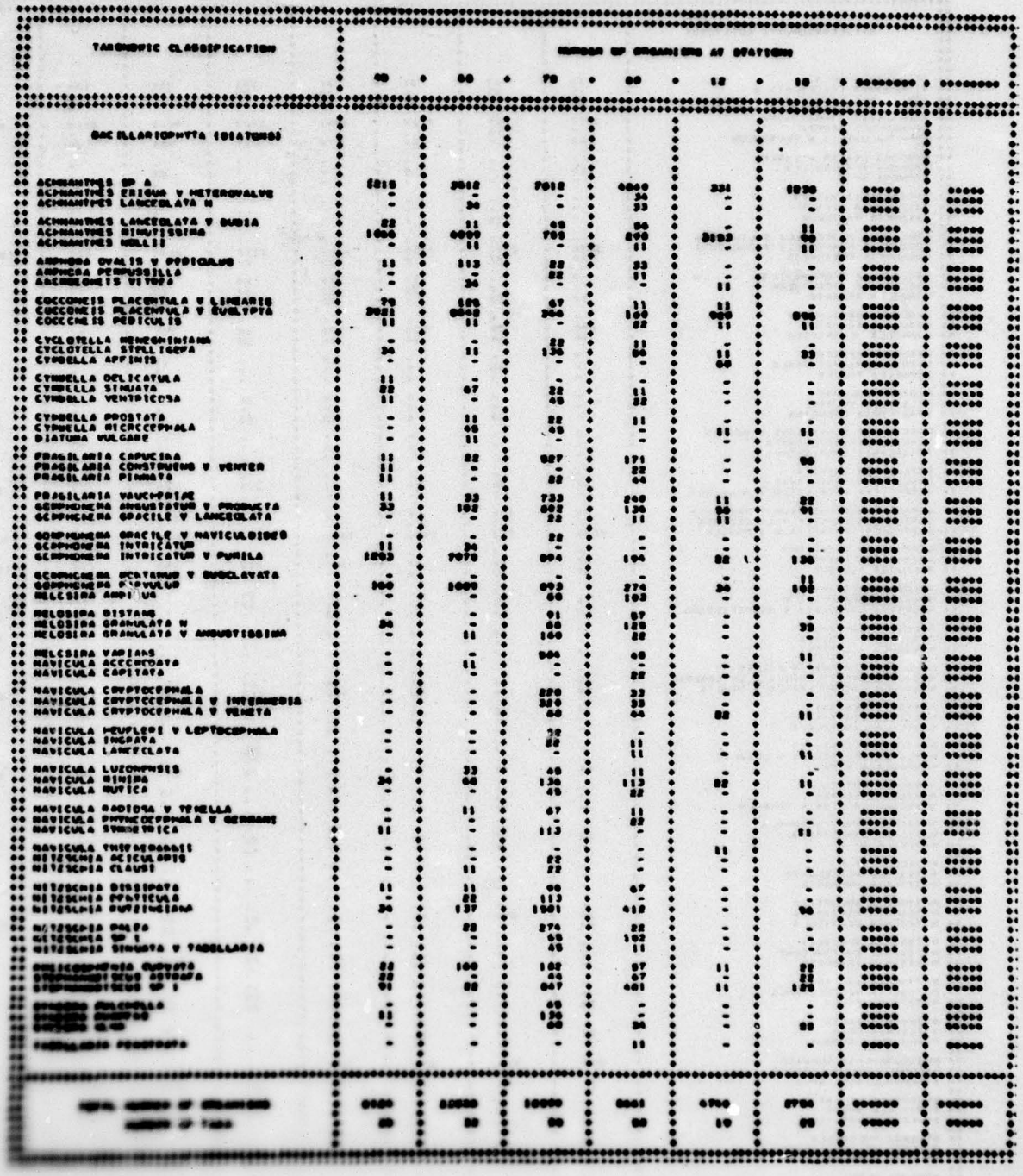

TABLE 10

PRESENCE-ABSENCE DATA FOR MICROBIAL ALGAE SPECIES RECORDED FROM HAAP ARTIFICIAL SUBSTRATES, JUNE, 1975

Species Observed	4B	6B	6A	7B	8B	14	17	18	20	12
Chlamydobacteriales										
Sphaerotilus natans				X	X	X				
Chlorophyceae										
Rhizoclonium sp.									X	
Stigeoclonium tenue	X	X	X	X	X	X	X	X	X	
Cyanophyceae										
Microcoleus lynbaeceus						X				
Oscillatoria submembranceae	X	X	X	X	X	X	X	X	X	X
Schizothrix arenaria	X		X		X	X		X	X	X
Schizothrix calcicola	X	X	X	X	X	X	X	X	X	X
Schizothrix mexicana							X		X	
Protozoans										
Carchesium polypenium	X	X		X	X	X				
Epistylis sp.	X	X		X	X	X				
Vorticella sp.	X			X	X					

TABLE 11

DIATOM TAXA OBSERVED ON HAAP NATURAL SUBSTRATES. JUNE SURVEY (CELLS/MM^2)

Counts Based on Pooled Replicates

TAXONOMIC CLASSIFICATION	NUMBER OF ORGANISMS AT STATION:								
	10	40	30	60	20	#####	#####	#####
BACILLARIOPHYTA (DIATOMS)								
ACHNANTHES AFFINIS	88	30	38	9	19	#####	#####	#####
ACHNANTHES COARCTATA	7	1	1	2	-	#####	#####	#####
ACHNANTHES DEFLEXA	-	-	-	-	-	#####	#####	#####
ACHNANTHES LANCEOLATA U	8	8	7	11	1	#####	#####	#####
ACHNANTHES LANCEOLATA V DUBIA	68	68	22	44	20	#####	#####	#####
ACHNANTHES MINUTISSIMA	68	81	22	44	20	#####	#####	#####
ACHNANTHES SP 1	-	-	2	-	1	#####	#####	#####
AMPHIPLEURA PELLUCIDA	-	-	2	-	1	#####	#####	#####
AMPHORA PERPUSSILLA	-	7	24	6	19	#####	#####	#####
AMPHORA SP 1	6	28	11	17	19	#####	#####	#####
CALONEIS BACILLUM	6	8	11	8	1	#####	#####	#####
COCCONEIS PLACENTULA V LINEARIS	19	8	10	1	-	#####	#####	#####
COCCONEIS PLACENTULA V EUGLYPTA	88	18	18	18	19	#####	#####	#####
COCCONEIS PEDICULUS	19	19	5	3	2	#####	#####	#####
COCCONEIS SP 1	-	1	-	-	-	#####	#####	#####
CYCLOTELLA GLOMERATA	-	-	-	-	-	#####	#####	#####
CYCLOTELLA MENEGHINIANA	-	-	-	-	-	#####	#####	#####
CYCLOTELLA STELLIGERA	23	7	19	19	12	#####	#####	#####
CYMBELLA AFFINIS	19	-	-	19	8	#####	#####	#####
CYMBELLA SINUATA	17	28	19	19	12	#####	#####	#####
CYMBELLA VENTRICOSA	-	28	19	-	12	#####	#####	#####
CYMBELLA PROSTATA	28	8	-	-	12	#####	#####	#####
CYMBELLA MICROCEPHALA	-	8	-	-	12	#####	#####	#####
CYMBELLA TUMIDA	-	-	-	-	-	#####	#####	#####
DIPLONEIS SP 1	-	-	-	-	-	#####	#####	#####
DIATOMA VULGARE	-	19	-	11	88	#####	#####	#####
FRUSTULIA VULGARE	-	8	-	19	4	#####	#####	#####
FRAGILARIA CAPUCINA	19	8	28	28	19	#####	#####	#####
FRAGILARIA PINNATA	-	8	-	28	19	#####	#####	#####
FRAGILARIA VAUCHERIAE	-	7	-	-	19	#####	#####	#####
GOMPHONEMA CONSTRICTUM	-	-	3	-	-	#####	#####	#####
GOMPHONEMA OLIVACEUM	28	8	7	7	8	#####	#####	#####
GOMPHONEMA PARVULUM	28	8	7	7	8	#####	#####	#####
GOMPHONEMA SP 1	-	-	-	-	-	#####	#####	#####
SYNEDRA SP	8	7	28	7	8	#####	#####	#####
MELOSIRA DISTANS	8	7	28	7	12	#####	#####	#####
MELOSIRA GRANULATA U	19	8	19	7	8	#####	#####	#####
MELOSIRA GRANULATA V ANGUSTISSIMA	8	19	19	19	28	#####	#####	#####
MELOSIRA VARIANS	-	19	19	7	28	#####	#####	#####
MERIDION CIRCULARE	38	19	-	38	19	#####	#####	#####
NAVICULA CRYPTOCEPHALA V INTERMEDIA	38	19	8	38	19	#####	#####	#####
NAVICULA LANCEOLATA	1	19	8	38	19	#####	#####	#####
NAVICULA LUZONENSIS	-	-	-	-	-	#####	#####	#####
NAVICULA MINIMA	28	19	37	19	28	#####	#####	#####
NAVICULA MUTICA	-	-	-	-	8	#####	#####	#####
NAVICULA PUPULA	-	-	-	-	-	#####	#####	#####
NAVICULA RADIOSA U	3	1	3	-	-	#####	#####	#####
NAVICULA SYMMETRICA	3	1	6	7	8	#####	#####	#####
NAVICULA VIRIDULA	8	7	19	28	28	#####	#####	#####
NAVICULA SP 1	8	28	19	48	28	#####	#####	#####
NAVICULA SP 2	8	8	19	8	1	#####	#####	#####
NAVICULA SP 3	8	8	28	8	8	#####	#####	#####
NAVICULA SP 4	3	19	12	8	8	#####	#####	#####
NITZSCHIA AMPHIBIA	3	2	8	-	-	#####	#####	#####
NITZSCHIA DISSIPATA	88	38	38	38	38	#####	#####	#####
NITZSCHIA DENTICULA	88	19	38	38	38	#####	#####	#####
NITZSCHIA KUTZINGIANA	68	19	82	28	68	#####	#####	#####
NITZSCHIA LINEARIS	1	-	-	-	1	#####	#####	#####
NITZSCHIA PALEA	19	38	19	19	38	#####	#####	#####
NITZSCHIA PARVULA	7	38	8	7	68	#####	#####	#####
NITZSCHIA RECTA	-	-	-	-	-	#####	#####	#####
NITZSCHIA SP 1	-	-	-	-	-	#####	#####	#####
RHOICOSPHENIA CURVATA	10	19	7	19	28	#####	#####	#####
STEPHANODISCUS ASTRAEA	8	19	-	8	19	#####	#####	#####
STEPHANODISCUS SP 1	3	-	-	3	-	#####	#####	#####
SURIRELLA LINEARIS	3	-	8	3	1	#####	#####	#####
SURIRELLA OVATA	8	1	8	8	-	#####	#####	#####
SURIRELLA SP 1	8	7	8	8	1	#####	#####	#####
SYNEDRA ACUS	8	7	8	8	1	#####	#####	#####
SYNEDRA PULCHELLA	8	7	38	1	-	#####	#####	#####
SYNEDRA RADIANS	3	-	3	-	-	#####	#####	#####
SYNEDRA RUMPENS V FAMILARIS	3	-	-	-	8	#####	#####	#####
SYNEDRA ULNA	8	8	8	1	-	#####	#####	#####
UNIDENTIFIED TAXA								
UNIDENTIFIED SPECIES 1	1	3	1	1	8	#####	#####	#####
UNIDENTIFIED SPECIES 2	-	-	-	-	-	#####	#####	#####
TOTAL NUMBER OF ORGANISMS	900	921	940	902	810	######	######	######
NUMBER OF TAXA	63	86	69	80	66	#####	#####	#####

surveys, by the Department of the Army (1974) and the USEPA (1973) have identified these sources as the HAAP production area A STP; the Kingsport municipal STP; the Tennessee Eastman Company (including toxic materials such as trichlorobenzene, trichloroaniline, and the heavy metals, zinc and manganese); Mead Papers; ASG Industries, Inc.; and the Penn-Dixie Cement Corporation.

At the HAAP effluent outfall stations (7B, 8B and 14) the dominant filamentous organism was Sphaerotilus natans. Chemical data indicate that these stations were receiving high levels of carbon and nitrogen, which may be responsible for the luxuriant growths of Sphaerotilus. Hynes (1966) reported S. natans to occur below organic pollution outfalls with similar massive growths. Lackey and Wattie (1940) report this organism to flourish in the presence of organic and inorganic carbon or nitrogen. Liebman (1953) indicates that it thrives where amino-acids are present from protein breakdown, especially when mixed with carbohydrates as in the effluents from sugar factories, breweries and dairies.

Significant increases in heterotrophic biomass and the establishment of a Sphaerotilus dominated periphyton community at Stations 7B, 8B, and 14 are probably the result of extensive carbon enrichment from the HAAP waste product, Cyclohexanone. Odors of this organic chemical were readily detected near the outfall pipes at Stations 7 and 8.

Another common organism of the Sphaerotilus-Stigeoclonium flora found at Stations 7B, 8B and 14 were the colonial stalked protozoans Carchesium polypenium and Epistylis sp. Hynes (1966) reports these species in organically polluted water, particularly where there are large populations of bacteria with a good supply of oxygen. These are known to be important constituents in activated sludge and trickling filter systems and commonly occur downstream of STP outfalls. It should be noted that both of these species were observed at the upstream control stations, 4B and 6B, and may be responding to STP effluent.

In addition to Stigeoclonium tenue, five species of blue-green algae (Cyanophyceae) were common components of the periphyton. These included:

Microcoleus lynbaeceus
Oscillatoria submembranceae
Schizothrix arenaria
Schizothrix calcicola
Schizothrix mexicana

The presence of substantial Sphaerotilus growths along with sewage tolerant protozoan species indicates a major shift in filamentous periphyton community structure at the HAAP effluent stations. Continuous carbon and nitrogen enrichment such as TOC, TKN and NO_3-N appear to stimulate the production of lush growths of nuisance sewage bacteria and associated heterotrophic organisms. Total populations of chlorophyll bearing species are greatly reduced with the establishment of a predominately "consumer-type" flora and fauna.

Organic Biomass and Chlorophyll a. Assessing the impact of munitions wastes on periphytic production in the Holston River was complicated by (1) extreme variations in daily flow due to intermittent discharges from Fort Patrick Henry Dam, (2) the mixing of the North Fork in the waters of the South Fork of the river, and (3) upstream loadings from domestic and industrial discharges. The chloride and hardness data collected during daily flow variations in the South Fork indicated a widely fluctuating chemical environment. The chemical data showed that mixing of the North Fork and South Fork waters is incomplete between the upstream HAAP operating lines and Arnott Branch.

The discharge concentrations of munitions residues, reduced nitrogen compounds, organic solvents, and nitrates were highly variable. In addition, reduced nitrogen compounds, organic matter and RDX waste were discharged from the upstream outfalls of Stations 7 and 8 while Arnott Branch, Station 10, primarily received nitrogen compounds from the nitric acid manufacturing area. Munition effluents discharged at Station 10 were an order of magnitude less than at Stations 7 and 8.

Water quality analysis indicates that the major impact of munitions wastes should occur at Stations 14, 16, and 20 as the current transports these effluents along the north bank. Loss of periphytometers due to floating debris and turbulent flows in the impact area during the August-September survey created problems in establishing an adequate data base. Much of the interpretive work had to be based on the June-July, 2- and 4-week collections. Figures 31 and 32, and Table 12 plot chlorophyll a and Autotrophic Index values at the various biological sampling stations during June-July. The complete data base is tabulated in Appendix B.

Table 12 presents mean values for chlorophyll a and biomass. Considering only the 2-week biomass data, a trend toward higher levels in the general area of impact is suggested. No differences can be observed in the 4-week incubation period. Interpretation of biomass and plant pigment data can be masked by sloughing of periphyton from the glass slides and this particular problem may reflect the lower biomass of 4-week growth. However, there are trends which indicate a rapidly developing heterotrophic community, especially in parts of the impact area receiving organic carbon.

Field observations indicated heavy growth of Sphaerotilus natans in the impact area of Stations 7B, 8, and 14. These increases in heterotrophic biomass and high autotrophic indices at the outfall stations are probably the result of extensive carbon enrichment from cyclohexanone. Odors were readily detectable at Station 8. The low biomass at Station 17 indicates that little impact occurs between 6A and 17. Wastes from production lines do not affect the biological communities on the south side of the river. Autotrophic indices were reduced from 280 to 140 at Stations 20 and 12 indicating some recovery from carbon enrichment.

The results of the June-July 4-week incubations show that biomass was greatest at 6A, 6B, and 4B, and was higher than the impact stations 14, and 18 and the cross stream Station 17. Downstream at Stations 20 and 12, a general trend of decreasing biomass was noted, which was possibly influenced by the munitions wastes being discharged from Arnott Branch. Chlorophyll a data also illustrate a similar trend.

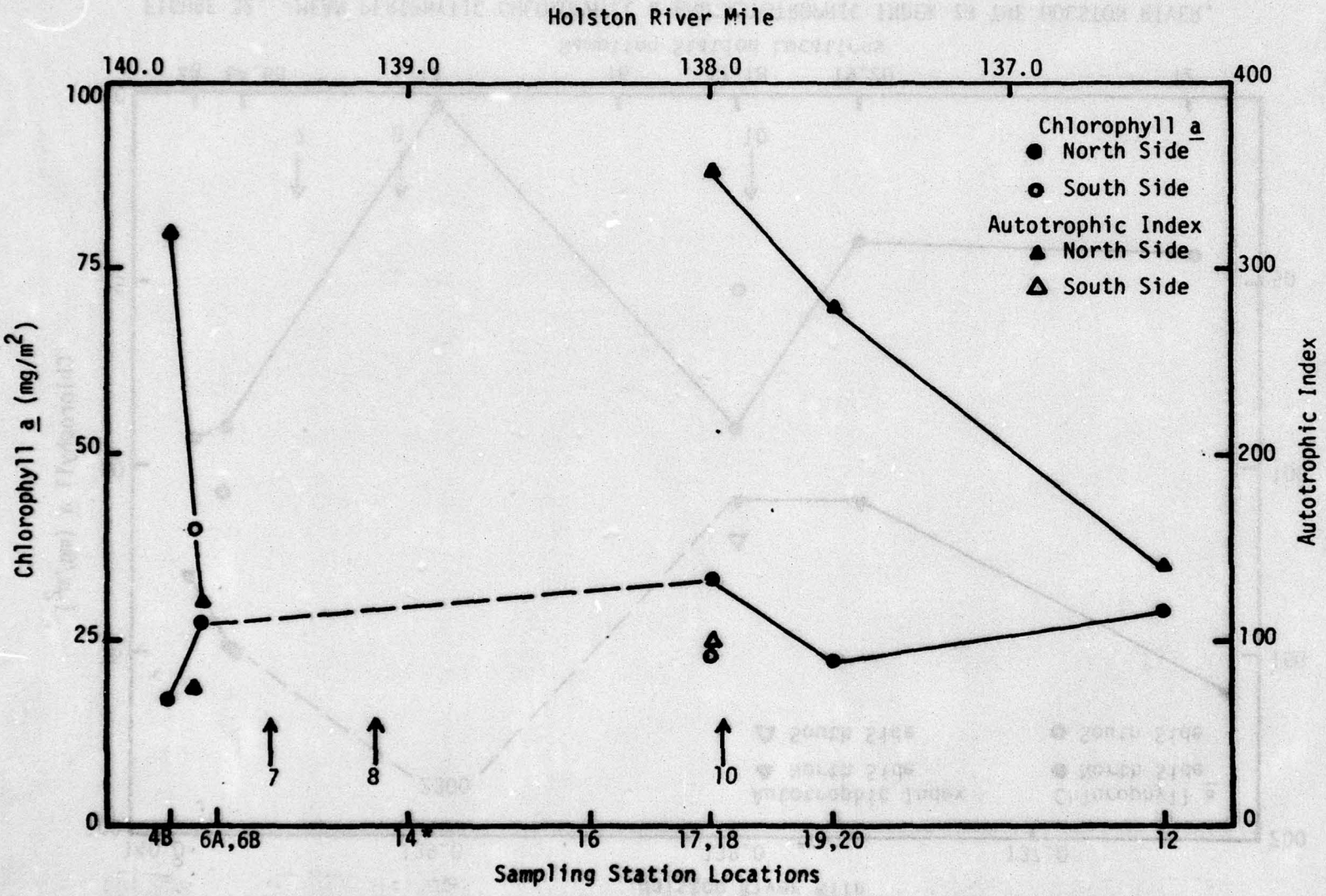

FIGURE 31. MEAN PERIPHYTIC CHLOROPHYLL a AND AUTOTROPHIC INDEX IN THE HOLSTON RIVER, JUNE-JULY, 1975, 2-WEEK INCUBATIONS

*Periphytometer lost

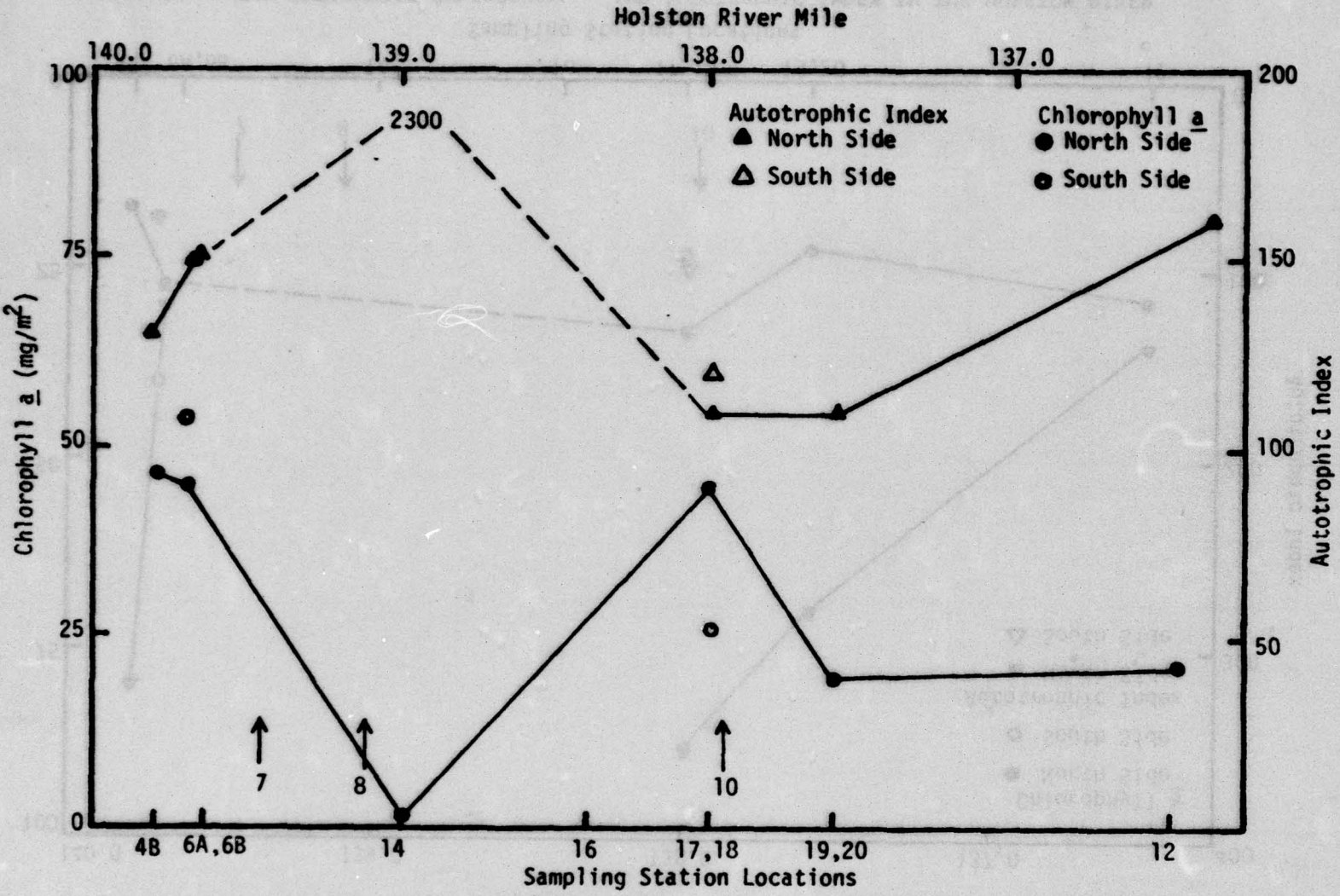

FIGURE 32. MEAN PERIPHYTIC CHLOROPHYLL a AND AUTOTROPHIC INDEX IN THE HOLSTON RIVER, JUNE-JULY, 1975, 4-WEEK INCUBATIONS

TABLE 12

MEAN CHLOROPHYLL a, ORGANIC BIOMASS AND AUTOTROPHIC INDICES,
HOLSTON RIVER ARTIFICIAL SUBSTRATES, JUNE-JULY 1975

Station	Two Week Incubations			Four Week Incubations		
	Chlorophyll a (gm/m^2)	Biomass (gm/m^2)	Autotrophic Index	Chlorophyll a (gm/m^2)	Biomass (gm/m^2)	Autotrophic Index
4B	0.017	5.40	320	0.041	5.52	130
6A	0.039	2.83	72	0.053	8.12	150
6B	0.027	3.33	120	0.039	5.80	150
14	---	5.81	---	0.002	4.60	2300
17	0.023	2.32	100	0.025	3.15	120
18	0.033	11.60	350	0.040	4.20	110
20	0.022	6.20	280	0.020	2.22	110
12	0.027	3.92	140	0.021	3.42	160

Rates of organic matter accumulation, or periphytic net community production, ranged from 0.04 to 0.41 gmC/m^2 day^{-1} with a mean 0.12, gmC/m^2 day^{-1} (Appendix B). A similar rate, 0.07-0.21 gmC/$m^2$$day^{-1}$ was found by Wietzel, et al. (1975). Rates of autotrophic accumulation were comparable to relatively unproductive attached systems (Odum, 1971; Jones, et al., 1973).

The chlorophyll a and biomass data suggest several conclusions regarding the growth of these attached communities. The presence of carbon enrichment from organic solvents in combination with nitrogen discharges from Stations 7 and 8 stimulate the production of a heterotrophic, nonchlorophyllous periphyton community at Station 14. There is suppression of autotrophic periphyton immediately below the production outfalls at Stations 7 and 8, compared to downstream stations.

Artificial Substrate Cell Densities. One of the first effects of pollution on periphyton community structure is to change the colonization or reproduction rates of diatom populations (Patrick, 1967). As a result, certain species may not be able to reproduce and may become extinct, while more tolerant species become more common because of less competition for nutrients, space, and a reduction in predator pressure.

In an effort to ascertain the effects of munitions waste discharges on the HAAP periphyton community, diatom cell densities (cells/mm^2) were determined for 2-week and 4-week incubation periods during June-July, 1975 and the first 2 weeks of August. Data for the last half of August were unavailable due to loss of periphytometers. After the initial colonization by pioneer species, the density of live diatom cells on glass slides increased to 10,500 cells ($\pm$ 5600 cells) per mm^2 in 28 days.

Figures 33, 34 and 35 plot mean cell densities and species diversity indices for the June-July and August 2- and 4-week incubation periods. In addition ranking of stations according to cell numbers is presented in Table 13. The data show higher diatom populations during the first 2-week period at stations upriver and on the opposite bank from the HAAP discharge. Stations 14, 18 and 20 which are located in the impact area have significantly reduced populations. These trends continue to be seen in the 4-week data and into the first half of August. Probable causes for these events are a heterotrophic metabolism from carbon enrichment and a toxic reaction from HAAP wastes.

Diatom Community Structure. A total of 114 species of diatoms representing 31 genera was recorded from the Holston River artificial substrate samplers. Diatom assemblages throughout the study period were characterized by the following common to dominant species:

Achnanthes minutissima
Coccoconeis placentula v. euglypta
Gomphonema intricatum v. pumila
Cymbella sinuata
Gomphonema angustatum v. producta
Gomphonema parvulum
Navicula cincta
Rhoicosphenia curvata
Stephanoidiscus sp. 1 (Near S. invisitatus)

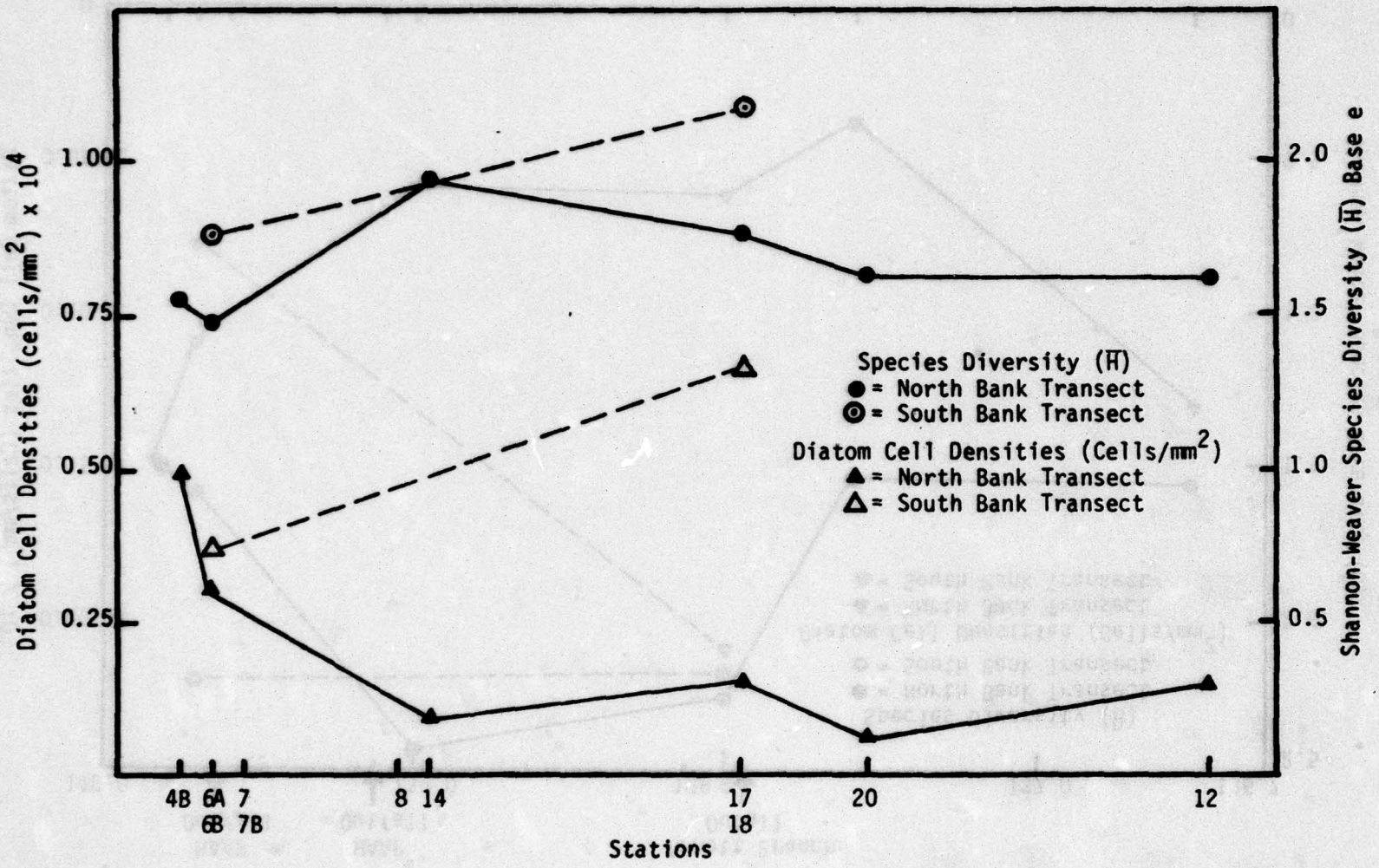

FIGURE 33 MEAN DIATOM CELL DENSITIES (CELLS/MM^2) AND SPECIES DIVERSITY INDICES ($\bar{H}$) FOR HAAP ARTIFICIAL SUBSTRATES FROM JUNE 1975, 2-WEEK HOLSTON RIVER, TENNESSEE

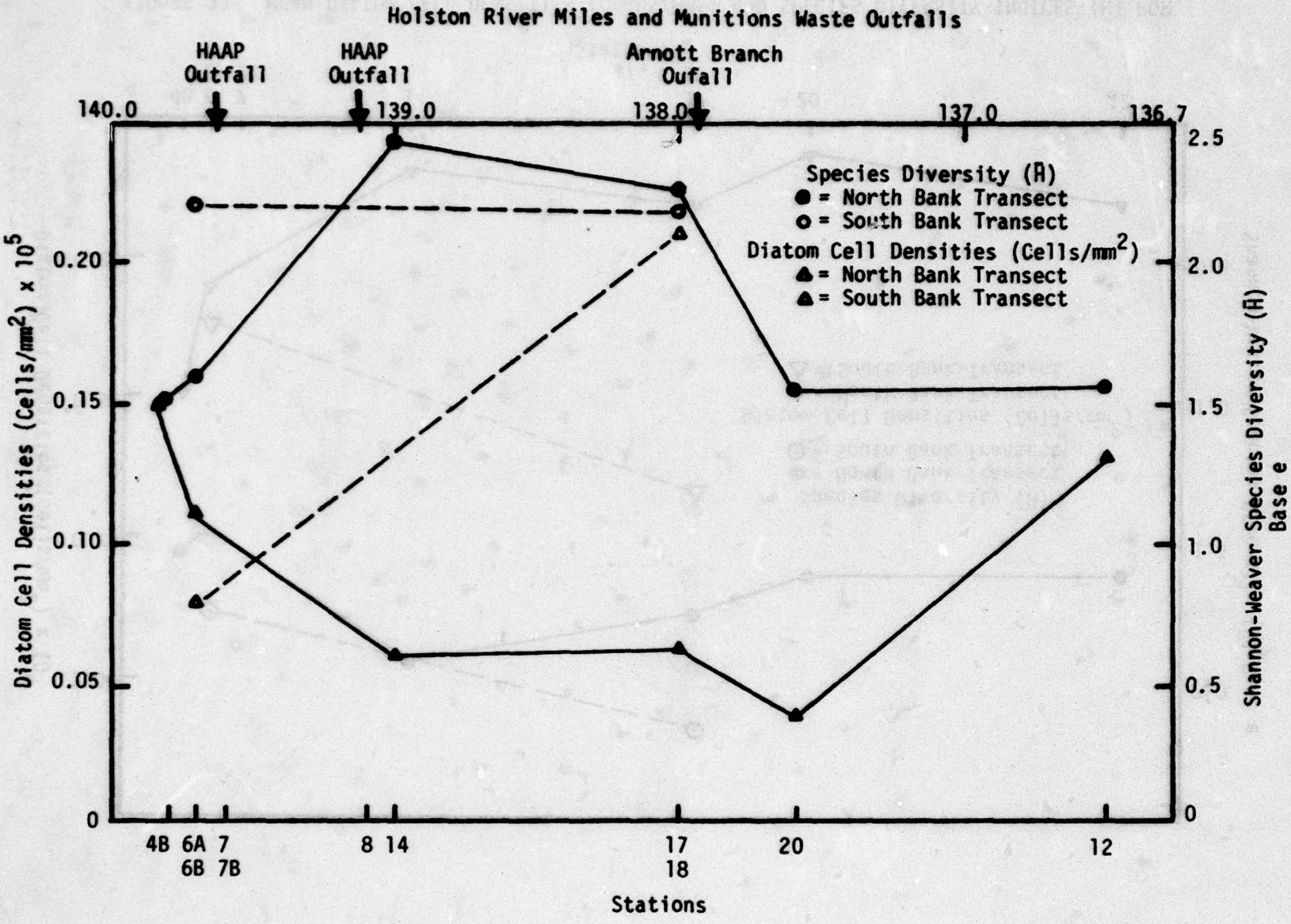

FIGURE 34 MEAN DIATOM CELL DENSITIES (CELLS/MM^2) AND SPECIES DIVERSITY INDICES ($\bar{H}$) FOR HAAP ARTIFICIAL SUBSTRATES, JUNE 1975, 4-WEEK, HOLSTON RIVER, TENNESSEE

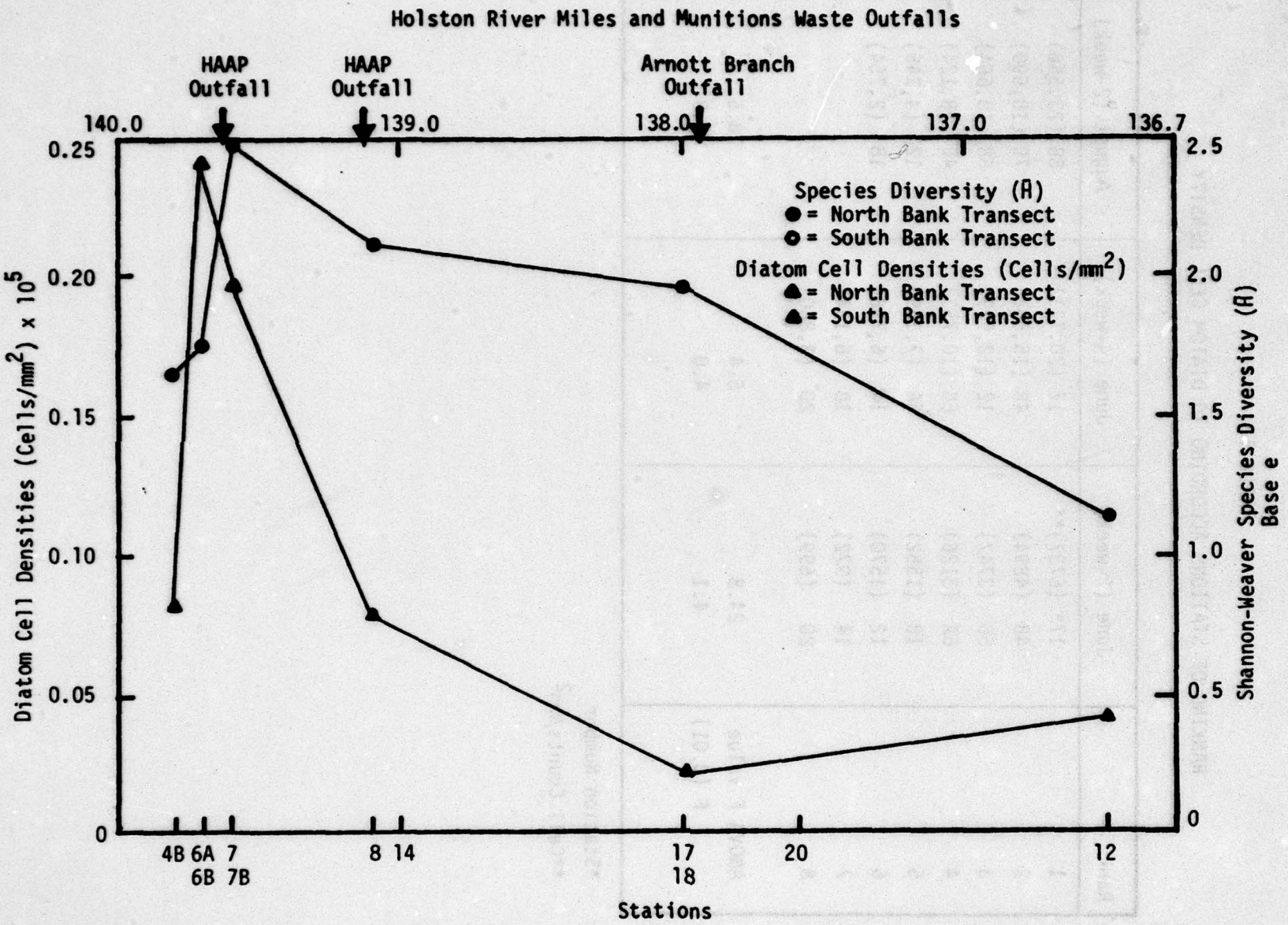

FIGURE 35. MEAN DIATOM CELL DENSITIES (CELLS/MM^2) AND SPECIES DIVERSITY INDICES ($\bar{H}$) FOR HAAP ARTIFICIAL SUBSTRATES, AUGUST 1975, 2-WEEK, HOLSTON RIVER, TENNESSEE

TABLE 13

RANKING OF STATIONS ACCORDING TO DIATOM CELL DENSITY

Rank	June (2-week)	June (4-week)	August (2-week)
1	17* (6737)**	17 (20,733)	6B (23,566)
2	4B (4894)	4B (15,568)	7B (18,590)
3	6B (3747)	12 (12,929)	8B (8,661)
4	6A (3126)	6B (10,753)	4B (8,124)
5	18 (1552)	6A (7,369)	12 (4,746)
6	12 (1570)	14 (6,718)	18 (2,754)
7	14 (972)	18 (6,134)	
8	20 (699)	20 (3,860)	
ANOVA F value	24.8	5.4	18.5
F (0.01)	4.1	4.0	8.8

*Station Number

**Cell Counts/mm^2

HAAP periphyton were primarily dominated by the following species associations during the June 2-week incubation period. Cocconeis placentula var. euglypta (43 percent), Gomphonema intricatum v. pumila (21 percent) and Achnanthes minutissima (14 percent). Early studies by Geitler (1927) indicate that Achnanthes and Cocconeis are usually the first algal forms to colonize glass slides. This is probably an indication that these species are not particularly selective about their substratum requirements. Collections during the June-July 4-week incubation period indicated several shifts in dominance as is presented in Appendix B, Tables B-5 to B-12. At Stations 4B, 14, 17 and 18 A. minutissima was the dominant species during this period (40 percent) followed by C. placentula v. euglypta (21 percent) and G. intricatum v. pumila (14 percent). However, a population shift in dominant species was noted at Stations 12 and 20: G. intricatum v. pumila replaced A. minutissima. G. intricatum v. pumila represented approximately 45 percent of the population at Station 12 and 20 followed by A. minutissima (27 percent) and C. placentula v. euglypta (17 percent).

The shift in diatom dominance observed below Station 18 during the June-July 4-week sampling period correlates with the reported increases in NO_3-N and RDX effluent entering the Holston River from Arnott Branch.

During the August-September 2-week sampling period a shift in diatom dominance and community structure was observed at the impact Station 7B and 8B and 18. The reference station co-dominant species, Cocconeis placentula v. euglypta and Gomphonema intricatum v. pumila were replaced by a diatom species tentatively identified as Achnanthes sp. A--ranging in relative abundance from 41-56 percent at the impact stations. However, by Station 12, diatom dominance was again shared by the normal river flora (i.e. Achnanthes minutissima and Cocconeis placentula v. euglypta)--which may indicate a recovery trend. The major changes in diatom dominance observed at the impact stations correlates with high levels of RDX, NO_3-N, TKN and TOC being discharged from the HAAP effluent lines. See Appendix B, Table B-1 for data.

These data illustrate periphyton response to munitions wastes by reducing the reproduction of the dominant diatom species, while favoring those species more resistant to high NO_3-N, and RDX concentrations. As a result, tolerant species increase. Patrick (1967) states that population increases in tolerant species may also be caused by the elimination of predator pressure (i.e. grazers) or by reducing the desirability of the food source to the predator.

The trophic level status of the common species recorded indicated a eutrophic diatom assemblage, characteristic of waters containing high nutrient concentrations. Butcher's (1947) study of glass slide diatom communities in European river systems reported Gomphonema parvulum and Cocconeis placentula v. euglypta as eutrophic diatom species associated with organic pollution. Scheele (1952) reports A. minutissima to be tolerant of a wide range of environmental conditions. Hustedt (1938) concludes that A. minutissima is one of the most cosmopolitan species known. Cholnoky (1968) states that this taxon is an indicator of waters containing a high dissolved oxygen content. Lowe (1974) citing Jorgensen (1948) reports G. intricatum v. pumila and

AD-A041 627 WATER AND AIR RESEARCH INC GAINESVILLE FLA F/G 13/2
AQUATIC FIELD SURVEY AT HOLSTON ARMY AMMUNITION PLANT, KINGSPOR--ETC(U)
JUN 77 J H SULLIVAN, H D PUTNAM, M A KEIRN DAMD17-75-C-5049
UNCLASSIFIED NL

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Rhoicosphenia curvata to be associated with eutrophic water quality conditions. Stephanodiscus invisitatus is recorded as a eutrophic water diatom species by Lowe and Crang (1972). The eutrophic status of the Holston River is further supported by the nutrient data collected during the June-July and August-September surveys where mean NO_3-N and Total-P averaged about 0.8 mg/l and 0.1 mg/l, respectively.

In an effort to compare the diatom assemblages present at each station, the following biological indices of community structure were utilized: Shannon-Weaver Species Diversity Index (Peilou, 1966); Sorensen's (1948) Coefficient of Similarity, and the Pinkham-Pearson (1974) Index of Biotic Similarity. For a brief review of these indices refer to the Computational Methods section.

Species diversity indices were relatively low throughout the study period (Table 14). The mean values ranged from 1.14 to 2.53 with an overall mean of 1.88. In general, stations located on the south side of the river (Stations 6A and 17) and near outfalls located on the north side of the river exhibited higher species diversity indices.

Data collected from Stations 14, 7B and 8B indicate that RDX and munitions residues had relatively little effect on diatom species diversity (H) and numbers of species. As noted previously, significant growths of Sphaerotilus and associated sewage protozoans were noted here. A high autotrophic index reflected the heterotrophic nature of these stations.

Coefficients of similarity (Sorensen, 1949) were high between upstream and downstream stations and most values exceeded the arbitrary 0.50 "significance" level reported by Cairns (1972). Tables B-16, B-17 and B-18 present the station-to-station similarity coefficients for HAAP artificial substrate diatom communities.

Lowest similarity values recorded during the June-July 2-week and 4-week sampling period were between stations 6A/20 and 6B/17. Similarity differences appear to be the result of a shift in diatom species dominance. At Station 20, there was a significant decrease in the diatom species Achnanthes minutissima, Gomphonema intricatum v. pumila, and Rhoicosphenia curvata. Station 6A experienced a population increase in the diatom Gomphonema angustatum v. producta. These shifts in diatom dominance may be attributed to differences in the chemical environment. RDX, chloride and nitrate concentrations were significantly greater at Station 20. Similarity coefficient differences between diatom assemblages at Stations 6B and 17 may be attributable to the intolerance of many species to high chloride and specific conductance levels reported along the north bank of the Holston River.

The highest coefficient of similarity during the study period was recorded between Stations 7B and 8B (0.82) during the August-September 2-week incubation period. Lowest similarity was between Stations 7B/12 and 8B/12 (0.435) which was probably due to a reduction in total number of species at Station 12 and the dominant diatom, Gomphonema intricatum v. pumila. Stations 7B and 8B both had 50 diatom species and was dominated by Achnanthes sp. A.

TABLE 14

MEAN SHANNON-WEAVER SPECIES DIVERSITY INDICES OF ARTIFICIAL SUBSTRATE PERIPHYTON (DIATOMS) COLLECTED FROM 2- AND 4-WEEK INCUBATION PERIODS IN THE HOLSTON RIVER, TENNESSEE

Station	River Mile	Species Diversity Indices[a]			
		Trip 1, 2-Week Incubation Period June 11-26,1975	Trip 1, 4-Week Incubation Period June 11-July 10, 1975	Trip 2, 2-Week Incubation Period Aug. 12-26, 1975	Trip 2, 4-Week Incubation Period Aug. 12-Sept. 7, 1975
4B	139.7	1.56[b]	1.52	1.64	
6A	139.6	1.78	2.24	L[d]	e
6B	139.6	1.47	1.59	1.74	
7B	139.5	NM[c]	NM	2.53	
8B	139.1	NM	NM	2.13	
14	139.0	1.95	2.45	L	
17	138.0	2.18	2.17	L	
18	138.0	1.77	2.25	1.97	
20	137.6	1.63	1.56	L	
12	136.3	1.62	1.58	1.14	

[a] Shannon-Weaver Species Diversity Index to the base e (Pielou, 1966)
[b] Mean values reported from 3 replicates
[c] NM = Not Measured
[d] L = Lost station due to floating debris
[e] Analysis of Trip 2, week 4 data was not performed. All slides except one impact station were lost due to flood and floating debris.

As an additional analysis, the Pinkham-Pearson Biotic Similarity Index (1974) was applied to the diatom data. Tables B-19 - B-24 present the results of station-to-station comparisons of biotic similarity. Phenograms using data from artificial substrates are illustrated in Figures 36, 37, and 38. In these analyses, it was considered unimportant if a particular species was mutually absent at two stations. Therefore, 0/0 matches were given a value of zero (mutual absence, unimportant).

The June-July 2-week phenogram (Figure 36) indicates that Stations 4B and 6B are at a high level of similarity and they appear to be independent of most downstream stations in terms of species composition and abundance. Stations 4B and 6B are located upstream from all munitions waste pollution and are reference stations. Stations 6A and 17 (south bank of river) cluster at a relatively low level of biotic similarity with other stations. Since these stations were affected by a different chemical environment (i.e. lower chlorides) and were generally out of the zone of RDX-NO_3-N influence--Stations 6A and 17 served as secondary reference stations to characterize water quality conditions on the south bank of the river.

A major munitions waste input was Arnott Branch, located between Stations 18 (upstream) and 20 (downstream). The phenogram (Figure 36) shows Station 12, located further downstream to be similar in species composition to station 18. Diatom assemblages at Stations 12 and 18 are more similar to each other than to Station 20 located between them in the zone of highest potential impact. Apparently, the effects observed at Station 20 do not persist as far downstream at Station 12. In terms of cell numbers per species, the diatom flora at Station 20 is reduced and does not cluster directly with the other downstream stations. The reduction in diatom cell densities may illustrate growth inhibition attributable to munitions waste discharged from Arnott Branch. Coefficients of similarity utilizing presence-absence data or the Shannon-Weaver ($\bar{H}$) index do not reflect the subtle uniqueness of the restricted diatom flora at Station 20.

Figure 37 presents the phenogram for the HAAP periphyton June-July 4-week incubation period, which illustrates a somewhat different clustering of stations in comparison with the 2-week sampling period. Stations 4B and 6B are again highly related but during the 4-week incubation period these two stations are also clustered with Station 12. This may represent a downstream recovery at Station 12. The most significant trend during the 4-week incubation period is the isolation of Station 20. During this period Station 20 exhibits a reduction in species diversity, numbers of species present, and biomass (grams carbon/m^2) which may result from effluents discharged into Arnott Branch.

Stations 14 and 18 illustrate a relatively high degree of similarity with higher numbers of diatom species present, species diversity ($\bar{H}$) and diatom cell densities per unit area.

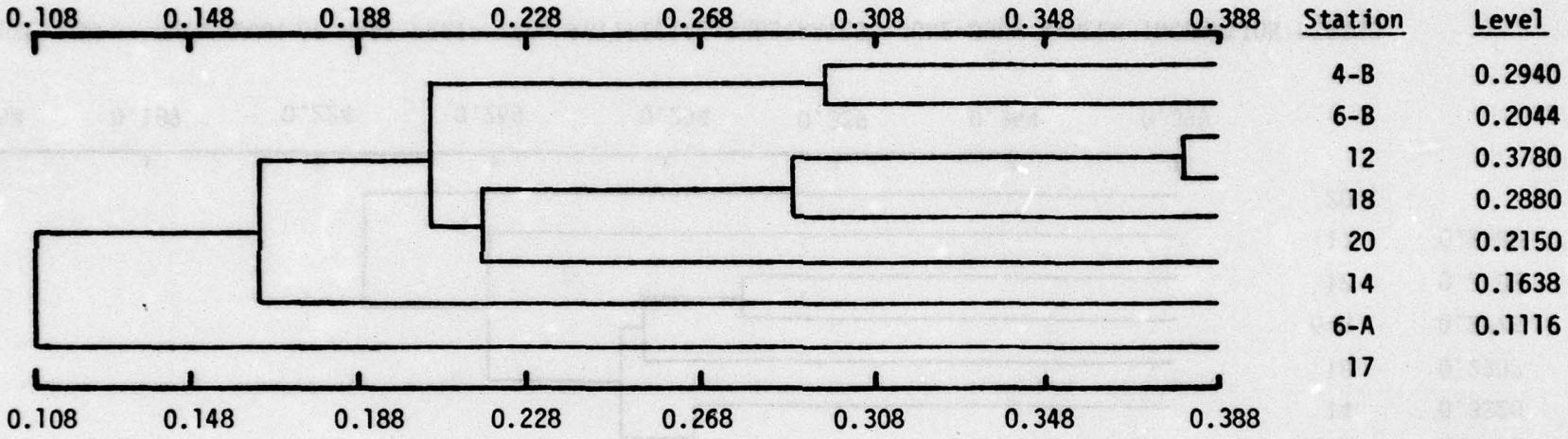


FIGURE 36. PHENOGRAM OF HAAP SAMPLING STATIONS BASED UPON THE PINKHAM-PEARSON BIOTIC SIMILARITY INDEX CALCULATED FROM ARTIFICIAL SUBSTRATE DIATOM COUNTS DURING THE JUNE 2-WEEK INCUBATION PERIOD. COPHENETIC CORRELATION COEFFICIENT, 0.927

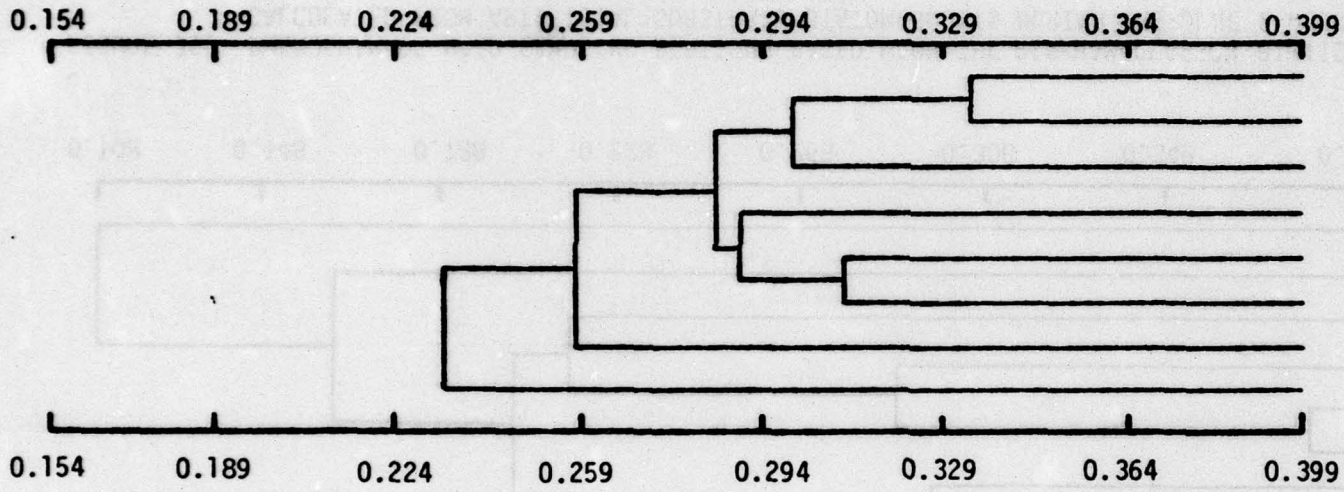


FIGURE 37 . PHENOGRAM OF HAAP PERIPHYTON ARTIFICIAL SUBSTRATES, JUNE-JULY 4-WEEK INCUBATION PERIOD

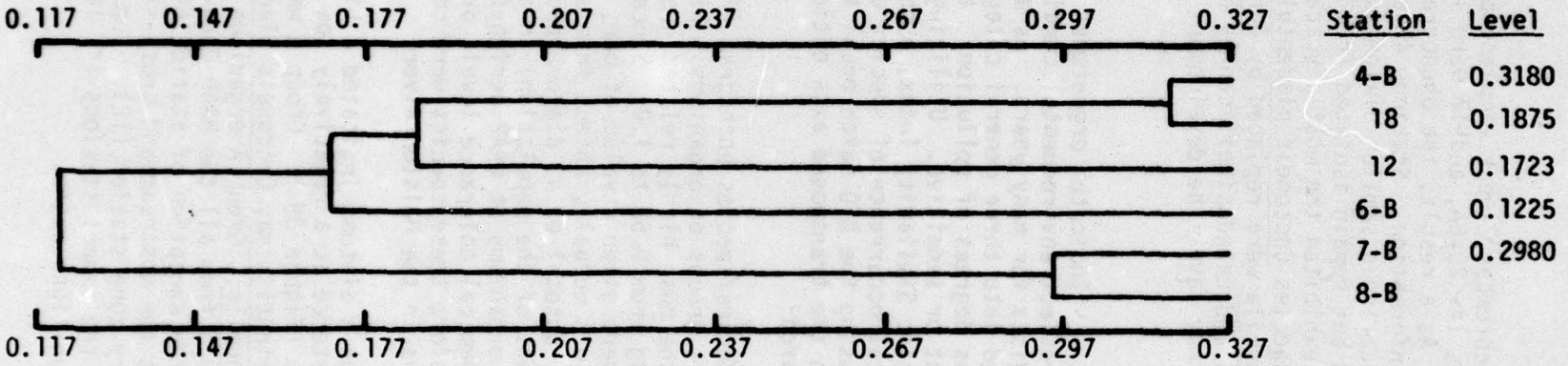


FIGURE 38. PHENOGRAM OF HAAP PERIPHYTON ARTIFICIAL SUBSTRATE, AUGUST 2-WEEK INCUBATION PERIOD. COPHENETIC CORRELATION COEFFICIENT, 0.860

During the August-September 2-week sampling period, artificial substrates located at Stations 14, 20,6A, and 17 were lost due to high river flow and floating debris. As a result, the phenogram illustrated in Figure 38 provides only limited information. Stations 4B and 18 cluster at a relatively high level indicating a similar diatom assemblage. Stations 7B and 8B are also correlated but remain isolated from other river stations. These two impact stations exhibited the most atypical diatom flora present as the dominant upstream species Cocconeis placentula v. euglypta and Gomphonema intricatum v. pumila were replaced by Achnanthes sp. A. Chemical data at stations 7B and 8B indicated significantly higher levels of RDX, NO_3-N, TOC and TKN, which may favor the development of more tolerant species.

Indicator Organisms. "Indicator organisms" -- i.e., individuals or groups of organisms that reflect environmental conditions -- have been of interest to aquatic ecologists for many years. As a result, a number of organisms have been grouped into three general categories in respect to their tolerance levels to various degrees of pollution: tolerant, intermediate or facultative, and intolerant or sensitive. Utilizing a variation of the Pinkham-Pearson (1974) Biotic Similarity Index, a phenogram was plotted, based on the spatial and numerical occurrence of species during the June - July 4-week incubation period. Using the 0/0 match equal to one, with group size being unimportant and with the transposed axis option; a species/species cluster analysis was prepared.

Analysis of the species/species phenogram (Figure 39) produces a clustering of five distinct groups of organisms. Diatom species clustered within Group F represent the most highly related group of organisms with Biotic Similarities ranging from 0.52 to 1.0. Since 0/0 matches (mutual absence) at each station were given a value of one, a high Biotic Similarity value indicates a species was mutually absent from a number of sampling stations. Group F represents a total of 42 diatom species which were recorded as rare (less than 1 percent of the population) throughout the study period. The occurrence of Group F organisms at HAAP periphyton stations indicates no specificity as to their chemical tolerance levels or habitat preferences between stations and therefore these species were considered poor indicators of environmental conditions in the Holston River.

In contrast, Group A diatoms indicated a high degree of similarity within the group, but clustered at a relatively low level with all other diatom groups in the study (Figure 39). Group A was comprised of three diatom species: Achnanthes minutissima; Cocconeis placentula v. euglypta; and Gomphonema intricatum v. pumila. Group A organisms represent the three dominant diatom species recorded from all the HAAP June-July 4-week periphyton sampling stations. With the exception of station 6A, populations of these three species were high at the upstream and cross-stream stations (4B, 6B, and 17) and at the recovery zone station (12). Populations of these organisms were reduced at the impact stations 14, 18, and 20 and may be considered sensitive to munitions waste.

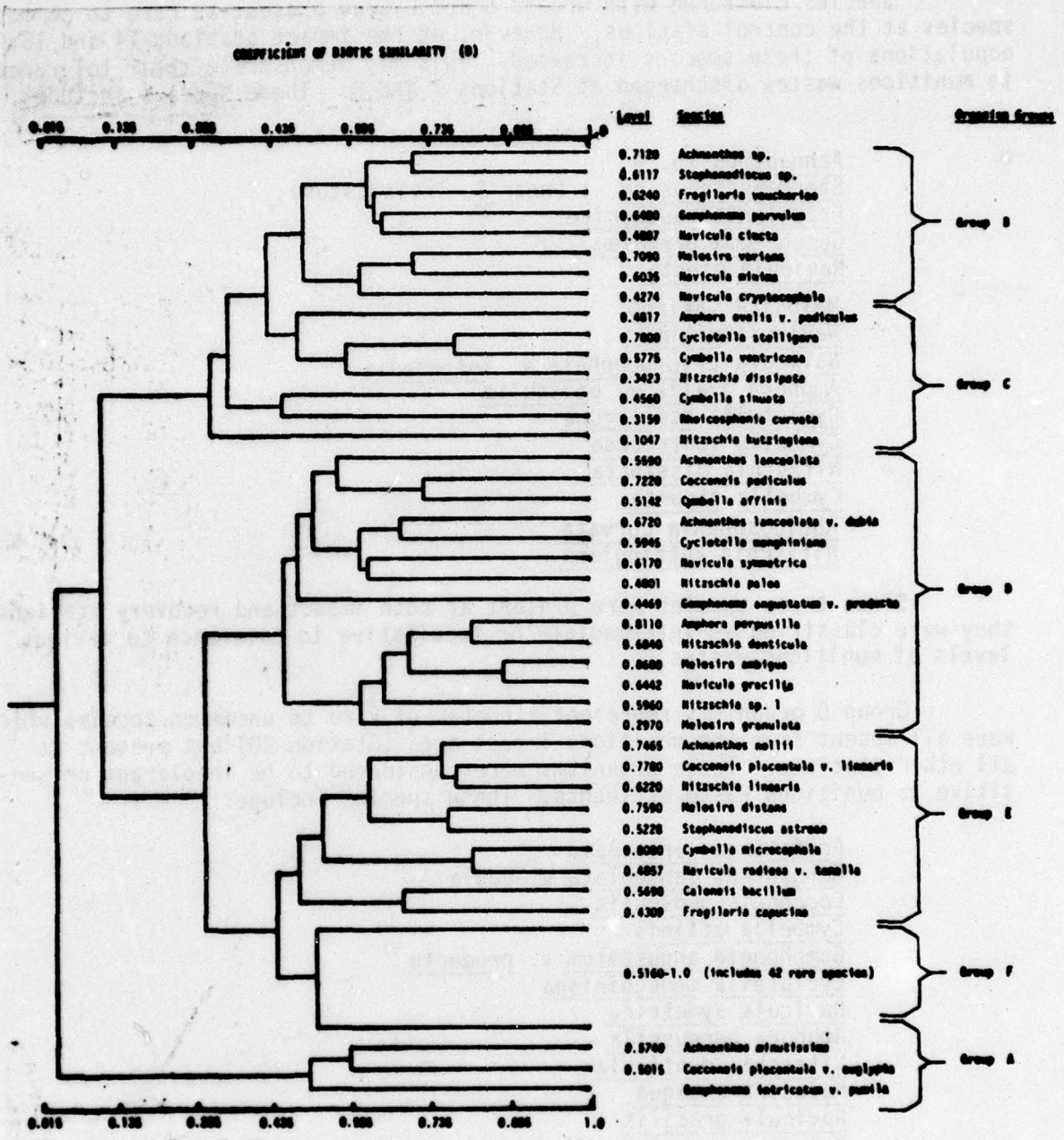


FIGURE 39. PHENOGRAM OF HAAP ARTIFICIAL SUBSTRATE DIATOM DATA: CLUSTER OF ORGANISMS BASED ON SAMPLE LOCATION, 4-WEEK INCUBATION PERIOD, JUNE 1975 O/O MATCHES = 1, GROUP SIZE UNIMPORTANT). COPHENETIC CORRELATION COEFFICIENT, 0.911

Species clustered with Groups B and C were present as rare to common species at the control stations. However, at the impact stations 14 and 18, populations of these species increased. This may demonstrate their tolerance to munitions wastes discharged at Stations 7 and 8. These species include:

Achnanthes sp. A
Stephanodiscus sp. 1 (near S. invisitatus)
Fragilaria vaucheriae
Gomphonema parvulum
Navicula cincta
Melosira varians
Navicula minima
Navicula cryptocephala v. intermedia
Amphora ovalis v. pediculis
Cyclotella stelligera
Cymbella ventricosa
Nitzschia dissipata
Cymbella sinuata
Rhoicosphenia curvata
Nitzschia kutzingiana

Since these species were present at both impact and recovery stations, they were classified as intermediate or facultative in tolerance to various levels of munitions wastes.

Group D organisms represent a number of rare to uncommon species which were all absent from the munitions impact area (Station 20) but present at all other stations. These organisms were considered to be intolerant or sensitive to munitions waste effluents. These species include:

Achnanthes lanceolata
Achnanthes lanceolata v. dubia
Cocconeis pediculis
Cymbella affinis
Gomphonema angustatum v. producta
Cyclotella meneghiniana
Navicula symetrica
Amphora perpussila
Nitzschia denticula
Melosira ambigua
Navicula gracilis
Melosira granulata
Nitzschia sp. 1
Nitzschia palea

The presence of Nitzschia palea, Melosira granulata and a number of other eutrophic indicator species within Group D is of interest. The literature reports N. palea to be an obligate nitrogen heterotroph (Cholnoky 1968), tolerant of a wide range of ecological conditions (Schroeder, 1939). In large numbers it reflects gross organic pollution (Weber, Raschke, 1966).

Absence of a population increase of N. palea at Station 20--in response to nitrate input from the Arnott Branch indicates that the impact of munitions waste upon this indicator species is relatively insignificant.

Organisms clustered within Group E represent those species which were entirely absent from the upstream Station 4B, and to a large extent, absent from Stations 20 and 12. Group E was comprised of the following species:

Achnanthes nollii
Cocconeis placentula v. linearis
Nitzschia linearis
Melosira distans
Stephanodiscus astraea
Cymbella microcephala
Navicula radiosa v. tenella
Caloneis bacillum
Fragilaria capucina

Their absence at the upstream station reflects their intolerance to pollutants impacting Station 4B from upriver sources at selected stations below 4B. These species were common components of the periphyton community but were largely absent at Stations 20 and 12. As a result, the clustering of these organisms may reflect their sensitivity to both organic and munitions waste pollution.

Natural Substrate Diatom Community Structure. Table 11 presents a detailed taxonomic list of diatom species recorded from HAAP natural periphyton substrates. Appendix B provides a synopsis of the percent relative abundance of the most common species. Table 15 presents the tabulated Shannon-Weaver ($\bar{H}$) species diversity indices, and Shannon evenness values (J) for the diatom populations. Holston River natural substrate diatom community structure was significantly different than diatom populations recorded from glass slides incubated for 2- and 4-week periods. Natural diatom populations revealed a much larger distribution of individuals among the taxa. As a result, the Shannon-Weaver species diversity indices ($\bar{H}$) were significantly higher than the artificial substrates. Species diversity indices ranged from 3.39 (Station 14) to 3.68 (Station 6B) while Shannon evenness values ranged from 0.895 (Station 12) to 0.915 (Station 6B). The highest species diversity index recorded for the artificial substrates diatom community was 2.54 (Table 14).

Total number of species was higher for the natural substrate communities than for the glass slide diatom populations--with 44-59 species reported from the 500 valve count data.

Comparisons of species between the natural and artificial substrates also indicated substantial dissimilarities. The most common diatom species from all natural substrate samples was Achnanthes minutissima--ranging in percent abundance from 5.5 to 10.4 percent. The most striking feature of the natural substrate community was the absence of two important colonizers

TABLE 15

SHANNON-WEAVER SPECIES DIVERSITY INDICES AND SHANNON EVENNESS VALUES FOR HAAP NATURAL SUBSTRATE DIATOMS, NORTH BANK OF HOLSTON RIVER, JUNE, 1975

Station	Species Diversity ($\bar{H}$)*	Evenness (J)**
4B	3.56	0.874
6B	3.68	0.915
14	3.39	0.896
18	3.54	0.910
12	3.54	0.892

*Shannon-Weaver index ($\bar{H}$) to the base e (Pielou, 1966; Odum, 1971).
**Shannon Evenness (J) (Pielou, 1966, Odum, 1971).

of the glass slide community, e.g. Gomphonema intricatum v. pumila and Cocconeis placentula v. euglypta. Early studies by Geitler (1927) indicated that Achnanthes and Cocconeis were usually the first species to colonize most glass slide communities. This probably indicates that these species are not particularly selective about their substratum. Geitler also noted that the species most frequently colonizing glass slides were flora characteristic of submerged mosses and stones.

No trends were observed in the natural substrate communities that could be attributable to the HAAP effluent waste discharges. Species diversities remained high at both reference and impact stations. No significant changes in species composition were noted between the reference and impact stations as patterns of species dominance were highly variable at all station locations.

From these data, periphytic diatoms collected from the blue-green algae mats indicated a poor correlation with the glass slide diatom community. The reasons for these differences are not known but may be influenced by differences in current, shading, substrate specificity, periods of low flow where the algae mats may be exposed to the air, differences in predator-prey pressures, and possible metabolic inhibitors produced by the extensive filamentous blue-green algae mats.

Significant increases in heterotrophic biomass, the reduction of chlorophyll bearing species, and the establishment of a Sphaerotilus (sewage bacterium) dominated community were observed in the vicinity of the two HAAP waste outfall sites (i.e. Stations 7B, 8B, and 14). This was probably the result of carbon enrichment from munitions waste, such as cyclohexanone.

Reductions in species diversity and shifts in diatom species associations suggest response to the wastes of RDX munitions manufacture. The following effects of RDX effluents were observed: (1) the normal invading periphytic flora were not killed--but could not reproduce, (2) tolerant species become more common because of less competition for nutrients and space, and were able to reproduce with populations of variable size, (3) the number of species surviving were high, but the number of individuals per species were significantly reduced--producing a Shannon-Weaver index that did not discriminate between subtle changes in community structure, and (4) the total biomass of the community was reduced.

MACROINVERTEBRATES

Introduction

Aquatic macroinvertebrates are a diverse group of small aquatic animals too large to pass through a U.S. Standard No. 30 mesh screen. They are comprised of snails, clams, arthropods, annelids (segmented worms and leeches), planarians, and coelenterates. Of these, oligochaetes account for the majority of the organisms in this study.

Aquatic macroinvertebrates are a major biological component of aquatic systems and form an important part of the food chain. They feed on detritus and microscopic plants and animals. They are in turn eaten by small fish which support the larger recreationally and economically important species. They are of special importance in stream environments because of their role in recycling large amounts of organic detritus introduced from uplands.

Macroinvertebrate species composition (density and diversity) is dependent primarily on three factors -- water quantity, water quality, and substrate composition.

Water quantity limits species within a site. For example, some prefer large, deep streams while others are found in smaller, shallower streams with numerous riffle areas.

Water quality is a significant factor in determining the assemblage of macroinvertebrates. Principal parameters include oxygen, temperature, hardness, and dissolved solids. The most important of these is oxygen. While many species require oxygen-saturated water in order to thrive, others can tolerate reduced oxygen tensions. Aquatic macroinvertebrates are also affected by temperature extremes. The Aquatic Life Advisory Committee (1956) indicates that benthic communities in the temperate zones are adapted to seasonal fluctuations of temperature between 0 and 32°C (32-90°F).

Substrate is the most important determinant in species composition (Hynes, 1960). There is a direct relationship between amounts of available surface area and species abundance and diversity. That is to say, there are more hiding and foraging places in a rock or pebble bottom than in a sand or mud bottom. The amount of organic matter, particularly from plants, is also important. Aquatic plants increase the abundance and diversity of benthic organisms viz. there is more surface area, periphytic food organisms, food from the plants themselves, and detritus on which to feed. Beck (1954) states, "...after careful examination of many streams, diversity of fauna was primarily the result of one factor -- the diversity of habitat."

Aquatic macroinvertebrates were chosen as a parameter for this study because they are important indicators of water quality, sensitive to environmental changes. Thus natural or man-induced fluctuations in the physical-chemical characteristics of a stream system are reflected by shifts in benthic community structure.

Historically, benthic macroinvertebrates have been employed in environmental surveys because they have a relatively short life span -- a year or less usually -- and, therefore, reflect present and recent past conditions as they tend to remain at fixed locations. Because of these two factors, benthic macroinvertebrates are useful as an integrated monitor of the environment.

Methods

Stations were located upstream, within and downstream of the potential impact area from HAAP effluents. Macroinvertebrates from natural substrates were collected in June and again in August, 1975. At selected stations, Hester-Dendy artificial plates were incubated twice during the summer. These were examined for degree of colonization during a 4-week period. The location and description of the biotic sampling stations are presented in Table 6. In general, the study concentrated on the station array along the north bank, since data from the June survey indicated that HAAP wastes were confined to the flow along the north bank of the river above Station 18.

Dye study results (Water Quality) indicate that South Fork water primarily influences the biota along the south bank of the river from Station 6A downstream to the highway bridge. Because of restricted mixing of North and South Fork water in the study reach, the South Fork waters appear to contain no munitions waste. Therefore, south bank biota are probably not influenced at all by munitions compounds.

Natural substrates were sampled with a petite Ponar dredge. Hester-Dendy artificial substrates were suspended approximately 1-3 feet below the surface. In the field, grabs of the natural substrate were washed in a bucket sieve (U.S. Standard No. 30 mesh) and bottled. Rose Bengal dye was then added to facilitate laboratory sorting. Samples were preserved in 10 percent Formalin. Natural substrates were rewashed in the laboratory. Hester-Dendy substrates were collected in the following manner. Plates were individually bagged in numbered cloth bags with the appropriate spacers. The plates from each sample were bagged together and the replicate samplers from each station stored in a roper bucket preserved with 10 percent Formalin. Macroinvertebrates from both types of substrate were sorted in a white enamel pan partially filled with water.

Taxa were identified using standard techniques to the lowest practical taxonomic level. Verification of selected chironomids was made by Mr. W.C. Beck of Florida A & M University. Representative specimens of oligochaetes were verified by Richard Jones of the Florida Department of Environmental Regulation. Key taxonomic references used in this study were: Parrish (1968), Usinger (1956), Mason (1973), Beck (1975a), Ross (1944), Edmondson (1959), and Pennak (1953).

The community structure indices computed for aquatic macroinvertebrates are the Shannon-Weaver Species Diversity Index, Evenness, and Pinkham-Pearson Index of Similarity.

Presentation of Data

Description of Taxa. Oligochaetes were the dominant benthic macroinvertebrates collected in the HAAP study area. They were found at all stations and accounted for 76 percent of the benthic organisms collected. In the June-July survey, oligochaetes totaled 50 percent of the population. Taxonomic lists by station are presented in Tables 16 to 19.

These organisms commonly inhabit a mud or detritus bottom. Growths of aquatic plants effectively increase numbers of taxa and individuals. Plants provide shelter from the current and predators and also produce detritus as food. Oligochaetes are generally recognized (Paine and Gaufin, 1956; Weber, 1973) as tolerant to moderately tolerant of high organic and nutrient concentrations and depressed oxygen levels. Since low oxygen inhibits most organisms, oligochaetes are favored by reduced competition and predation.

Oligochaetes are valuable contributors to the cycling of energy and materials (carbon, nutrients, etc.) in stream systems. River environments contrast with lakes and reservoirs in that substantial energy to the lotic system comes indirectly from the sun through detritus (leaves, twigs and other organic materials). Detritus is initially decomposed by bacteria and fungi and consumed by oligochaetes (and other organisms). Oligochaetes in turn are a food base for small forage fish, juvenile gamefish, and predaceous macroinvertebrates.

Counts for this group are reported as "Oligochaeta." Among those identified were Limnodrilus, a Tubificid; and Nais, Paranais, Pristina, and Stylaria sp. -- all Naididae.

Leeches were present at all stations from both natural and artificial substrates. Five unidentified taxa were recognized as "Hirudinea species A through E." Leeches are very similar to oligochaetes in that they prefer slowly moving water, and are able to tolerate environments with moderate to high organic content. Leeches require substrates to which their caudal suckers can adhere; they prefer rocky or vegetated areas. Most species are free living but some exhibit a parasitic existence.

Chironomid (non-biting midge fly) larvae were abundant. They colonized both natural and artificial substrates. Chironomids as a group can be found in nearly every habitat including coastal zones (Oliver, 1971). They are found in all types of stream environments from the cleanest to the most polluted water. Because they inhabit such a wide variety of ecological niches, they are one of the most important indicator organisms (Beck, 1975b ; Paine and Gaufin, 1956). They have been the subject of numerous studies regarding their taxonomy, habitat preferences, pollution tolerances, and general ecology. The most common midge in natural substrates at HAAP was Chironomus attenuatus. This pioneer species is a freshwater form which can tolerate a wide range of pH, turbidity, and organic enrichment. It has been reported as a scavenger (Roback, 1953) and as a predator (Godhaus, 1967). The stomach contents of Holston River specimens were composed of detritus, inorganics (sand and clay) and algae.

Ecology of the two other predominate chironomid species (Psectrocladius and Cricotopus sp.1) is not well understood. Psectrocladius was the dominate organism on artificial substrates and was collected at all stations except Stations 7B and 8B. These stations were influenced by HAAP waste especially organic compounds which may have prevented colonization by this species. Cricotopus sp.1 described by Beck (1975 a,b) is a distinctive species which has not been reared in the laboratory and is unnamed. Beck characterizes the organism as preferring neutral to slightly alkaline water. It will tolerate some organic enrichment, as long as the dissolved oxygen level is 5 mg/l or greater.

Physa sp. occurred in tremendous numbers often covering large sections of exposed river bank. Extremely large populations of these pulmonate snails colonized weed beds near the south bank where they apparently were feeding on periphyton. Sphaerium sp. was the only bivalve collected and only in the natural substrates. This small fingernail clam was common in dredge samples.

Planarians (Turbellaria species A and B) were abundant. They often dominated the fauna on artificial substrate samplers. They were present at all stations except 8B.

All of these (along with the more uncommon taxa) are generally considered tolerant or facultatively tolerant to nutrient and organic pollution (Weber, 1973; Beck, 1975b; Paine and Gaufin, 1956). Their dominance at all stations indicates eutrophic conditions in the Holston River which supports the prior findings of Smock and Stoneburner (1973).

Density of each taxon based on pooled replicates by station is presented in Tables 16 thru 19. Histograms showing populations size and distribution of taxa are presented in Figures 40 and 41. As is evident during both surveys the number of organisms in river sediments immediately below HAAP outfalls was low compared to other north bank stations. This trend is not apparent on artificial substrates exposed in this same area and the two sets of data are, therefore, somewhat anomolous. The data from dredge samples suggest recovery at Station 12. There is no apparent correlation between macroinvertebrate population and levels of munitions wastes in sediments.

Species diversity values are shown in Table 20. Upstream of the effluent discharge at Station 6B, macroinvertebrates were more diverse ($\bar{H}$) on artificial substrates (2.2) than they were immediately downstream of the outfalls (1.4, 1.1, 0.9).

Diversity of benthic macroinvertebrates changed little from the June-July to August-September sampling trips. However, a significant increase occurred at Station 20, and was likely due to the oxygenating effect of the riffle area on the warmer (late summer) river waters. Five times as many chironomid taxa were found in the later sampling.

The similarity of stations is shown in Figures 42 through 45, using phenograms of the Pinkham-Pearson Index of Biotic Similarity (mutual absence unimportant).

TABLE 16

HAAP MACROBENTHOS NATURAL SUBSTRATE, JUNE 1975
(Counts based on pooled replicates [Organisms/m^2])

TAXONOMIC CLASSIFICATION	NUMBER OF ORGANISMS AT STATION: 4B	6A	6B	7B	12	14	16	17
MACROBENTHOS								
HIRUDINEA SP A	-	190	16	-	239	58	-	81
HIRUDINEA SP B	-	181	41	25	274	163	86	298
HIRUDINEA SP C	16	1204	8	-	17	205	-	8
HIRUDINEA SP D	-	8	-	33	8	8	43	-
HIRUDINEA SP E	-	-	-	-	1924	223	-	17
OLIGOCHAETA	946	7634	1471	738	20409	11039	4938	8878
PHYLUM ARTHROPODA - CLASS INSECTA								
ORDER ODONATA								
NEHALENNIA SP	-	-	-	-	8	-	-	-
ORDER HYMENOPTERA								
UNIDENTIFIABLE HYMENOPTERA	-	-	-	-	-	-	16	-
ORDER COLEOPTERA								
NARPUS SP	-	-	8	-	-	-	-	-
UNIDENTIFIABLE ELMIDAE	-	-	-	-	-	8	-	-
UNIDENTIFIABLE COLEOPTERA	-	-	-	-	-	-	16	-
ORDER DIPTERA - FAMILY CHIRONOMIDAE								
ABLABESMYIA PHILOSPHAGNOS	-	-	-	-	8	-	16	8
CHIRONOMUS ATTENUATUS	16	41	8	304	33	162	-	-
CONCHAPELOPIA SP	-	-	-	8	17	8	-	-
CRICOTOPUS BICINCTUS	-	33	-	8	-	94	-	85
CRICOTOPUS REMUS	-	16	-	-	-	-	-	-
CRICOTOPUS SP A	-	34	41	16	232	34	28	-
CRYPTOCHIRONOMUS FULVUS	-	-	-	-	-	8	-	-
CRYPTOCHIRONOMUS SP A	-	-	-	-	-	-	-	-
EINFELDIA SP	-	-	-	8	-	-	-	-
HARNISCHIA SP	-	-	-	-	-	8	-	-
KIEFFERULUS SP	-	-	-	-	-	8	-	-
POLYPEDILUM CONVICTUM	-	8	-	8	-	25	-	-
POLYPEDILUM FALLAX	-	-	-	-	-	8	-	-
POLYPEDILUM HALTERALE	16	-	-	-	-	-	-	-
POLYPEDILUM ILLINOENSE	-	-	-	17	8	34	-	88
PROCLADIUS SP	-	8	-	-	25	-	-	-
PSECTROCLADIUS SP	-	8	-	-	8	8	116	-
RHEOTANYTARSUS SP	-	-	-	8	-	-	-	8
TRIBELOS SP A	-	-	-	17	-	24	16	-
ORDER DIPTERA - OTHER								
CERATOPOGONIDAE UNIDENTIFIABLE	-	-	-	-	-	-	-	8
SIMULIIDAE UNIDENTIFIABLE	-	-	-	-	-	8	-	166
DIPTERA UNIDENTIFIABLE	-	-	-	-	-	-	-	-
PHYLUM COELENTERATA								
HYDRA SP	-	-	-	-	8	-	-	-
PHYLUM MOLLUSCA								
CLASS GASTROPODA								
PHYSA SP	-	74	-	43	25	200	-	-
GASTROPODA SP C	-	66	-	-	-	-	-	-
GASTROPODA UNIDENTIFIABLE	16	-	-	-	-	8	-	-
CLASS PELECYPODA								
SPHAERIUM SP	-	42	16	-	70	170	187	102
PHYLUM NEMATODA								
NEMATODA	-	66	17	88	33	136	-	88
PHYLUM TURBELLARIA								
TURBELLARIA SP A	-	-	-	-	42	88	816	-
TURBELLARIA SP B	-	-	-	8	1848	992	917	847
TOTAL NUMBER OF ORGANISMS	1002	9907	1606	1190	24242	13376	6926	8894
NUMBER OF TAXA	5	16	9	15	20	26	12	14

TABLE 16 (CONTINUED).

TAXONOMIC CLASSIFICATION	NUMBER OF ORGANISMS AT STATION:							
	18	20	.....	.....	.....	.....	.....	.....
MACROBENTHOS								
HIRUDINEA SP A	17	8	.....	.....	.....	.....	.....	.....
HIRUDINEA SP B	60	839	.....	.....	.....	.....	.....	.....
HIRUDINEA SP C	-	-	.....	.....	.....	.....	.....	.....
HIRUDINEA SP D	-	-	.....	.....	.....	.....	.....	.....
HIRUDINEA SP E	200	-	.....	.....	.....	.....	.....	.....
OLIGOCHAETA	7316	1093	.....	.....	.....	.....	.....	.....
PHYLUM ARTHROPODA - CLASS INSECTA								
ORDER ODONATA								
NEHALENNIA SP	8	-	.....	.....	.....	.....	.....	.....
ORDER HYMENOPTERA								
UNIDENTIFIABLE HYMENOPTERA	-	-	.....	.....	.....	.....	.....	.....
ORDER COLEOPTERA								
HARPUS SP	-	-	.....	.....	.....	.....	.....	.....
UNIDENTIFIABLE ELMIDAE	-	-	.....	.....	.....	.....	.....	.....
UNIDENTIFIABLE COLEOPTERA	-	-	.....	.....	.....	.....	.....	.....
ORDER DIPTERA - FAMILY CHIRONOMIDAE								
ABLABESMYIA PHILOSPHAGNOS	-	-	.....	.....	.....	.....	.....	.....
CHIRONOMUS ATTENUATUS	42	-	.....	.....	.....	.....	.....	.....
CONCHAPELOPIA SP	-	-	.....	.....	.....	.....	.....	.....
CRICOTOPUS BICINCTUS	-	-	.....	.....	.....	.....	.....	.....
CRICOTOPUS REMUS	-	-	.....	.....	.....	.....	.....	.....
CRICOTOPUS SP A	-	16	.....	.....	.....	.....	.....	.....
CRYPTOCHIRONOMUS FULVUS	-	-	.....	.....	.....	.....	.....	.....
CRYPTOCHIRONOMUS SP A	8	-	.....	.....	.....	.....	.....	.....
DIMPELOSIA SP	-	-	.....	.....	.....	.....	.....	.....
HARNISCHIA SP	-	-	.....	.....	.....	.....	.....	.....
KIEFFERULUS SP	-	-	.....	.....	.....	.....	.....	.....
POLYPEDILUM CONVICTUM	-	8	.....	.....	.....	.....	.....	.....
POLYPEDILUM FALLAX	-	-	.....	.....	.....	.....	.....	.....
POLYPEDILUM HALTERALE	-	-	.....	.....	.....	.....	.....	.....
POLYPEDILUM ILLINOENSE	8	8	.....	.....	.....	.....	.....	.....
PROCLADIUS SP	17	-	.....	.....	.....	.....	.....	.....
PSPECTROCLADIUS SP	-	-	.....	.....	.....	.....	.....	.....
RHEOTANYTARSUS SP	-	-	.....	.....	.....	.....	.....	.....
TRIBELOS SP A	8	-	.....	.....	.....	.....	.....	.....
ORDER DIPTERA - OTHER								
CERATOPOGONIDAE UNIDENTIFIABLE	-	-	.....	.....	.....	.....	.....	.....
SIMULIDAE UNIDENTIFIABLE	-	-	.....	.....	.....	.....	.....	.....
DIPTERA UNIDENTIFIABLE	-	8	.....	.....	.....	.....	.....	.....
PHYLUM COELENTERATA								
HYDRA SP	-	-	.....	.....	.....	.....	.....	.....
PHYLUM MOLLUSCA								
CLASS GASTROPODA								
PHYSA SP	-	25	.....	.....	.....	.....	.....	.....
GASTROPODA SP C	-	-	.....	.....	.....	.....	.....	.....
GASTROPODA UNIDENTIFIABLE	-	8	.....	.....	.....	.....	.....	.....
CLASS PELECYPODA								
SPHAERIUM SP	170	-	.....	.....	.....	.....	.....	.....
PHYLUM NEMATODA								
NEMATODA	160	16	.....	.....	.....	.....	.....	.....
PHYLUM TURBELLARIA								
TURBELLARIA SP A	68	-	.....	.....	.....	.....	.....	.....
TURBELLARIA SP B	168	-	.....	.....	.....	.....	.....	.....
TOTAL NUMBER OF ORGANISMS	8874	1429	.....	.....	.....	.....	.....	.....
NUMBER OF TAXA	14	10	.....	.....	.....	.....	.....	.....

TABLE 17
HAAP MACROBENTHOS NATURAL SUBSTRATE, AUGUST 1975
(Counts based on pooled replicates [Organisms/m^2])

TAXONOMIC CLASSIFICATION	NUMBER OF ORGANISMS AT STATION: 6B	6A	6C	7B	8B	8B1	12	13
MACROBENTHOS								
HIRUDINEA SP A	-	58	-	-	-	-	972	-
HIRUDINEA SP B	-	198	28	-	-	-	93	-
HIRUDINEA SP C	-	106	-	93	10	-	33	-
HIRUDINEA SP D	-	29	33	-	-	-	-	-
HIRUDINEA SP E	-	112	-	8	-	-	2428	-
OLIGOCHAETA	-	1304	9819	2049	161	914	7109	-
PHYLUM ARTHROPODA - CLASS CRUSTACEA								
ASELLUS SP	-	-	-	-	-	-	-	-
PHYLUM ARTHROPODA - CLASS INSECTA								
ORDER ODONATA								
DROPOGOMPHUS SP	-	-	8	-	-	-	-	-
LEUCORRHINIA SP	-	-	-	8	-	-	-	-
ORDER COLEOPTERA								
HETEROCERIDAE	-	-	-	-	-	-	-	-
UNIDENTIFIABLE COLEOPTERA	-	-	-	-	-	-	-	-
ORDER DIPTERA - FAMILY CHIRONOMIDAE								
BRILLIA SP	-	-	-	-	-	-	-	-
CHIRONOMUS ATTENUATUS	186	8	127	942	20	144	-	10
CLINOTANYPUS SP	-	-	-	-	21	-	-	-
CONCHAPELOPIA SP	87	8	-	42	-	8	8	127
CRICOTOPUS BICINCTUS	14	-	8	93	21	-	16	-
CRICOTOPUS REMUS	-	-	-	16	-	-	8	20
CRICOTOPUS SP A	-	8	-	-	-	-	-	20
CRYPTOCHIRONOMUS FULVUS	14	-	-	-	-	-	-	-
CRYPTOCHIRONOMUS SP A	-	-	-	-	-	8	-	-
CRYPTOTENDIPES SP	-	-	-	-	-	-	-	-
GLYPTOTENDIPES SP	-	-	-	8	-	-	-	-
MICROTENDIPES SP	-	-	-	-	-	-	-	-
PARACHIRONOMUS MONOCHROMUS	-	-	-	-	-	-	-	10
PARACHIRONOMUS PECTINATELLAE	14	-	-	-	-	-	-	-
POLYPEDILUM CONVICTUM	14	-	-	17	10	-	8	30
POLYPEDILUM FALLAX	-	-	-	-	-	-	-	-
PROCLADIUS SP	-	-	25	-	10	17	17	-
PSECTROCLADIUS SP	-	-	-	8	10	8	-	-
TANYTARSUS SP	-	-	-	-	-	-	-	-
CHIRONOMIDAE UNIDENTIFIABLE	-	-	-	-	-	-	-	-
ORDER DIPTERA - OTHER								
CHAOBORUS SP	-	-	-	-	-	-	-	-
CHRYSOZONA SP	-	-	-	-	-	-	-	-
SIMULIUM SP	-	-	-	8	-	-	-	-
CERATOPOGONIDAE UNIDENTIFIABLE	-	-	-	-	-	-	-	-
DOLICHOPODIDAE	-	-	-	-	-	-	-	-
DIPTERA SP A	-	-	-	-	-	-	-	-
DIPTERA SP B	-	-	-	-	-	-	-	-
DIPTERA SP C	-	-	-	-	-	-	-	-
DIPTERA UNIDENTIFIABLE	-	-	-	8	-	-	-	-
PHYLUM COELENTERATA								
HYDRA SP	-	-	-	-	-	-	10	-
PHYLUM MOLLUSCA								
CLASS GASTROPODA								
PHYSA SP	-	111	99	2907	-	-	171	-
GASTROPODA SP C	-	-	-	-	-	-	-	-
CLASS PELECYPODA								
SPHAERIUM SP	-	8	498	8	-	-	270	-
PHYLUM NEMATODA								
NEMATODA	-	8	-	-	10	-	29	-
PHYLUM TURBELLARIA								
TURBELLARIA SP B	-	336	8	8	-	-	1031	-
TOTAL NUMBER OF ORGANISMS	299	2447	10943	9403	203	699	12209	217
NUMBER OF TAXA	6	13	10	16	9	6	19	6

TABLE 17 (CONTINUED).

TAXONOMIC CLASSIFICATION	NUMBER OF ORGANISMS AT STATION: 16	17	18	20	.....	.....	.....	.....
MACROBENTHOS								
HIRUDINEA SP A	96	17	120	103	.....	.....	.....	.....
HIRUDINEA SP B	79	334	150	222	.....	.....	.....	.....
HIRUDINEA SP C	42	34	-	810	.....	.....	.....	.....
HIRUDINEA SP D	8	-	-	-	.....	.....	.....	.....
HIRUDINEA SP E	203	-	927	75	.....	.....	.....	.....
OLIGOCHAETA	4200	6962	11000	602	.....	.....	.....	.....
PHYLUM ARTHROPODA - CLASS CRUSTACEA								
ASELLUS SP	-	-	-	8	.....	.....	.....	.....
PHYLUM ARTHROPODA - CLASS INSECTA								
- ORDER ODONATA								
DROMOGOMPHUS SP	-	-	-	-	.....	.....	.....	.....
LEUCORRHINIA SP	-	-	-	-	.....	.....	.....	.....
ORDER COLEOPTERA								
HETEROCERIDAE	8	-	-	-	.....	.....	.....	.....
UNIDENTIFIABLE COLEOPTERA	-	-	-	16	.....	.....	.....	.....
ORDER DIPTERA - FAMILY CHIRONOMIDAE								
BRILLIA SP	-	-	-	8	.....	.....	.....	.....
CHIRONOMUS ATTENUATUS	-	8	-	33	.....	.....	.....	.....
CLINOTANYPUS SP	-	-	-	-	.....	.....	.....	.....
CONCHAPELOPIA SP	8	90	-	70	.....	.....	.....	.....
CRICOTOPUS BICINCTUS	8	8	-	822	.....	.....	.....	.....
CRICOTOPUS VENUS	-	-	-	17	.....	.....	.....	.....
CRICOTOPUS SP A	-	-	-	-	.....	.....	.....	.....
CRYPTOCHIRONOMUS FULVUS	8	-	-	-	.....	.....	.....	.....
CRYPTOCHIRONOMUS SP A	-	-	-	-	.....	.....	.....	.....
CRYPTOTENDIPES SP	8	-	-	-	.....	.....	.....	.....
GLYPTOTENDIPES SP	-	-	-	-	.....	.....	.....	.....
MICROTENDIPES SP	-	-	-	8	.....	.....	.....	.....
PARACHIRONOMUS MONOCHROUS	-	8	-	-	.....	.....	.....	.....
PARACHIRONOMUS PECTINATELLAE	-	-	-	-	.....	.....	.....	.....
POLYPEDILUM CONVICTUM	-	-	-	127	.....	.....	.....	.....
POLYPEDILUM FALLAX	-	-	-	8	.....	.....	.....	.....
PROCLADIUS SP	24	-	-	-	.....	.....	.....	.....
PSECTROCLADIUS SP	-	16	-	-	.....	.....	.....	.....
TANYTARSUS SP	-	-	-	8	.....	.....	.....	.....
CHIRONOMIDAE UNIDENTIFIABLE	-	-	-	16	.....	.....	.....	.....
ORDER DIPTERA - OTHER								
CHAOBORUS SP	-	-	-	8	.....	.....	.....	.....
CHRYSOZONA SP	-	-	-	8	.....	.....	.....	.....
SIMULIUM SP	-	-	-	64	.....	.....	.....	.....
CERATOPOGONIDAE UNIDENTIFIABLE	-	-	-	8	.....	.....	.....	.....
DOLICHOPODIDAE	-	-	-	88	.....	.....	.....	.....
DIPTERA SP A	-	-	-	17	.....	.....	.....	.....
DIPTERA SP B	-	-	-	8	.....	.....	.....	.....
DIPTERA SP C	-	-	-	8	.....	.....	.....	.....
DIPTERA UNIDENTIFIABLE	-	-	-	-	.....	.....	.....	.....
PHYLUM COELENTERATA								
HYDRA SP	8	-	-	-	.....	.....	.....	.....
PHYLUM MOLLUSCA								
CLASS GASTROPODA								
PHYSA SP	999	16	-	993	.....	.....	.....	.....
GASTROPODA SP C	-	-	-	8	.....	.....	.....	.....
CLASS PELECYPODA								
SPHAERIUM SP	17	2532	301	700	.....	.....	.....	.....
PHYLUM NEMATODA								
NEMATODA	-	8	10	-	.....	.....	.....	.....
PHYLUM TURBELLARIA								
TURBELLARIA SP B	111	831	837	904	.....	.....	.....	.....
TOTAL NUMBER OF ORGANISMS	9476	10833	12060	9310	.....	.....	.....	.....
NUMBER OF TAXA	16	17	7	29	.....	.....	.....	.....

TABLE 18

HAAP MACROBENTHOS ARTIFICIAL SUBSTRATE, JUNE 1975
(Organisms/m^2)

Counts based on pooled replicates

TAXONOMIC CLASSIFICATION	NUMBER OF ORGANISMS AT STATIONS							
	04	08	12	14	17	18	20	
PHYLUM ANNELIDA								
HIRUDINEA SP B	101	-	-	11	000	0	11	00000
HIRUDINEA SP C	155	10	-	-	-	-	-	00000
HIRUDINEA SP E	33	-	-	-	-	-	-	00000
OLIGOCHAETA	300	001	017	11	1001	070	11	00000
PHYLUM ARTHROPODA - CLASS INSECTA								
ORDER EPHEMEROPTERA								
CAENIS SP	-	0	-	-	-	-	-	00000
EPHEMERA SP	-	10	-	-	-	-	-	00000
ORDER COLEOPTERA								
NARPUS SP	-	-	-	-	00	-	-	00000
ORDER DIPTERA - FAMILY CHIRONOMIDAE								
CARDIOCLADIUS SP (TENT.)	-	-	-	-	-	-	00	00000
CHIRONOMUS ATTENUATUS	11	-	-	-	00	-	00	00000
CONCHAPELOPIA SP	00	003	101	101	-	100	00	00000
CRICOTOPUS BICINCTUS	-	70	0	11	-	-	00	00000
CRICOTOPUS MODUS	-	30	10	-	-	00	100	00000
CRICOTOPUS SP A	-	110	01	03	-	00	130	00000
DICROTENDIPES LEUCOCELIS	-	10	-	-	-	-	-	00000
DICROTENDIPES NERVOSUS	-	0	-	-	-	-	-	00000
GLYPTOTENDIPES SP	-	07	-	-	-	-	11	00000
PARACHIRONOMUS MONOCHROUS	00	-	-	-	-	-	11	00000
POLYPEDILUM CONVICTUM	33	00	03	00	-	37	11	00000
POLYPEDILUM FALLAX	-	10	0	-	-	00	-	00000
POLYPEDILUM HALTERALE	-	10	-	-	-	10	-	00000
PSECTROCLADIUS SP	107	1001	10	00	11	-	33	00000
RHEOTANYTARSUS SP	-	70	-	-	-	0	00	00000
TANYTARSUS SP	-	0	-	-	-	-	-	00000
THIENEMANNIELLA SP A	00	71	07	03	-	10	33	00000
CHIRONOMIDAE UNIDENTIFIABLE	-	-	-	-	-	03	00	00000
ORDER DIPTERA - OTHER								
SIMULIUM SP	-	00	-	-	-	-	100	00000
UNSPECIFIED ORDER								
INSECTA UNIDENTIFIABLE	-	0	-	0	-	0	-	00000
PHYLUM COELENTERATA								
HYDRA SP	-	10	-	-	-	-	-	00000
PHYLUM MOLLUSCA								
CLASS GASTROPODA								
PHYSA SP	-	01	-	1300	-	0	11	00000
GASTROPODA UNIDENTIFIABLE	11	-	-	-	-	-	-	00000
CLASS PELECYPODA								
PELECYPODA UNIDENTIFIABLE	-	-	-	-	-	00	-	00000
PHYLUM NEMATODA								
NEMATODA	11	-	-	-	11	-	-	00000
PHYLUM TURBELLARIA								
TURBELLARIA SP A	000	-	01	101	01	101	070	00000
TURBELLARIA SP B		0				001		00000
TOTAL NUMBER OF ORGANISMS	1010	0000	000	0007	1700	1300	1170	00000
NUMBER OF TAXA	13	00	00	00	7	17	00	00000

TABLE 19

HAAP MACROBENTHOS ARTIFICIAL SUBSTRATE, AUGUST 1975
(Organisms/m^2)

Counts based on pooled replicates

TAXONOMIC CLASSIFICATION	NUMBER OF ORGANISMS AT STATIONS							
	04	05	70	08	10	13	14	15
PHYLUM ANNELIDA								
HIRUDINEA SP B	883	82	1472	671	33	94	83	11
HIRUDINEA SP C	-	85	858	-	-	-	-	-
HIRUDINEA SP E	-	-	-	-	-	-	-	-
OLIGOCHAETA	39	814	6004	2361	600	66	844	87
PHYLUM ARTHROPODA - CLASS INSECTA								
ORDER EPHEMEROPTERA								
STENONEMA SP	-	44	-	-	-	-	-	-
ORDER CORIXATA								
SPHAGONIA SP	-	11	-	-	-	-	-	-
HESPEROCORIXA SP	-	-	-	-	-	-	-	-
ORDER COLEOPTERA								
UNIDENTIFIABLE COLEOPTERA	-	11	-	-	-	-	-	-
ORDER DIPTERA - FAMILY CHIRONOMIDAE								
CHIRONOMUS ATTENUATUS	-	455	55	33	-	44	-	55
CONCHAPELOPIA SP	-	267	-	33	11	-	-	88
CRICOTOPUS BICINCTUS	-	-	-	-	-	-	-	-
CRICOTOPUS SYLVESTRIS GROUP	-	83	-	-	-	-	-	-
CRICOTOPUS TRIFASCIA	-	-	-	-	-	-	-	-
LAUTERBORNIELLA AGRAYLEYENSIS	-	-	-	11	-	-	-	-
PARAMETRIOCNEMUS STYLATUS	-	-	-	-	-	-	-	-
POLYPEDILUM CONVICTUM	83	166	11	116	11	11	11	66
POLYPEDILUM FALLAX	-	11	-	-	-	-	-	-
TANYTARSUS GLABRESCENS GROUP	-	322	88	-	11	83	-	88
TANYTARSUS SP B	-	-	11	-	-	-	-	-
CHIRONOMIDAE UNIDENTIFIABLE	-	-	11	-	11	-	-	-
PHYLUM COELENTERATA								
HYDRA SP	-	-	-	-	33	-	-	-
PHYLUM MOLLUSCA								
CLASS GASTROPODA								
PHYSA SP	766	66	36	83	466	827	888	616
GASTROPODA UNIDENTIFIABLE	-	-	-	-	83	-	-	-
PHYLUM NEMATODA								
NEMATODA	-	11	-	-	-	-	-	-
PHYLUM TURBELLARIA								
TURBELLARIA SP A	220	87	101	2000	1000	88	2322	100
TOTAL NUMBER OF ORGANISMS	2242	3520	8300	5910	2100	988	3800	1042
NUMBER OF TAXA	5	20	10	10	10	5	5	7

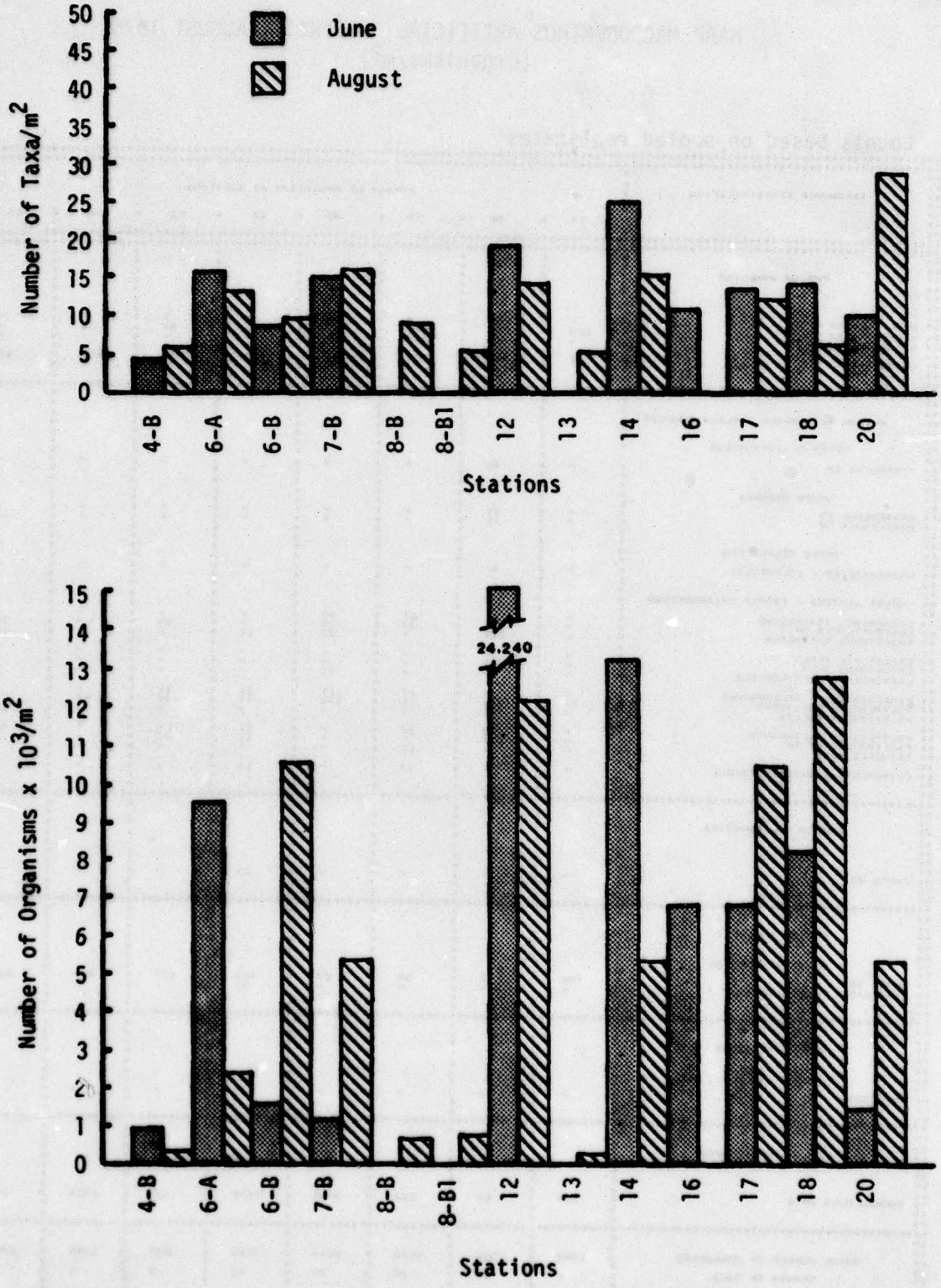


FIGURE 40 . TOTAL NUMBERS OF MACROINVERTEBRATE TAXA AND ORGANISMS COLLECTED FROM HAAP NATURAL SUBSTRATES

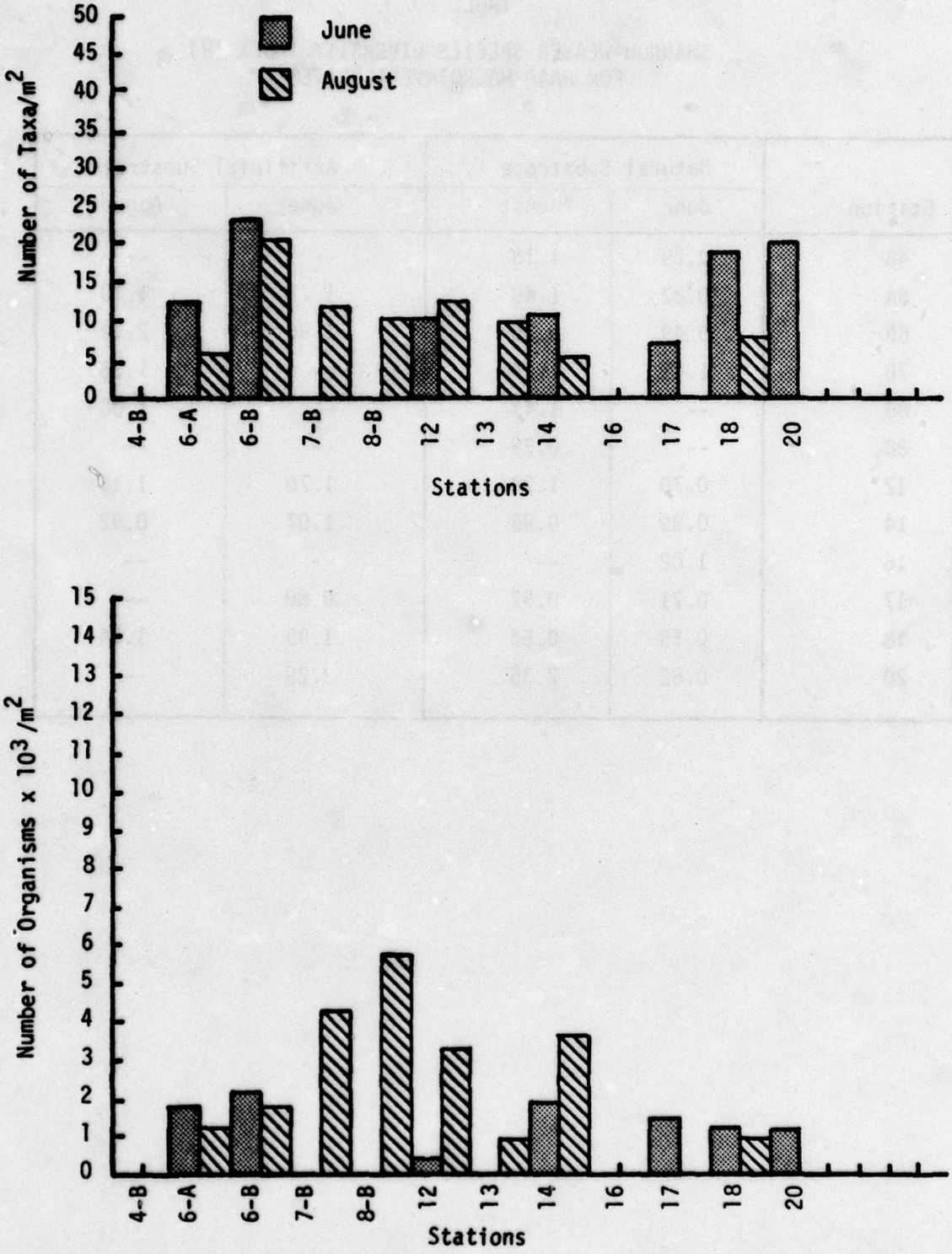


FIGURE 41 . TOTAL NUMBERS OF MACROINVERTEBRATE TAXA AND ORGANISMS COLLECTED FROM HAAP ARTIFICIAL SUBSTRATES

TABLE 20

SHANNON-WEAVER SPECIES DIVERSITY INDEX ($\bar{H}$)
FOR HAAP MACROINVERTEBRATES

Station	Natural Substrate		Artificial Substrate	
	June	August	June	August
4B	0.29	1.18	--	--
6A	0.82	1.49	1.72	1.10
6B	0.49	0.35	1.96	2.32
7B	1.42	1.24	--	1.35
8B	--	1.43	--	1.08
$8B_1$	--	0.79	--	--
12	0.70	1.30	1.70	1.16
14	0.89	0.89	1.07	0.92
16	1.02	--	--	--
17	0.71	0.97	0.80	--
18	0.59	0.63	1.89	1.34
20	0.82	2.35	2.29	--

Considering the phenographic displays for both natural and artificial substrates shown in Figures 42 through 45, certain general statements can be made regarding clustering of stations. In both the June and August surveys, station pairing and grouping occurred in a rather random manner such that south shore stations associated with those in the impact zone (Figure 43, 6A-20) and upstream reference stations grouped with impact stations (Figure 43, 6B-18). In only a few stations did pairing among impact stations occur (Figure 45, 7B-8B; Figure 44, 8B-$8B_1$; Figure 42, 7B-20).

Overall, the use of phenograms to aid in analysis of the macroinvertebrate data were not conclusive. Grouping of stations was not consistent in terms of their relative location either within or out of the potential impact area.

Effects of Munitions Compounds and Associated Residues

Environmental conditions in the Holston are such that an effects study strictly related to munitions waste is difficult. Both colonization of artificial substrates and examination of river sediments were employed to assess impact of HAAP wastes on macroinvertebrates. The two methods provide information related to different environments (i.e. water and substrate). The temptation to compare artificial substrate to natural should be avoided.

Our studies showed that effects on macroinvertebrates may result not only from RDX, but also associated carbon and nitrogen compounds. Therefore, field studies cannot isolate impact from RDX alone. Correlations may be expressed between biotic components and RDX in the tabular and graphic material, but it should be remembered that associated compounds also are present and undoubtedly influence the community.

Maximum impact in river sediments was observed just below the outfalls of the munition production lines at Station 7B, 8B and $8B_1$. Here Sphaerotilus growths were evident and the sediment exhibited reduced conditions. Although somewhat speculative, the macroinvertebrate community probably was responding to loading from organic carbon compounds. Populations at Stations 7, 8B and $8B_1$ and taxa at the latter two sampling points represented minimums observed during the study. The impact observed below the HAAP outfalls (7 and 8) are restricted to a short zone of the river extending approximately 100 to 200 yards downstream. Whole river effects are not discernible. Response downriver to nitrogen loading from Arnott Branch may in part be reflected at Station 20 (June) by lowered diversity.

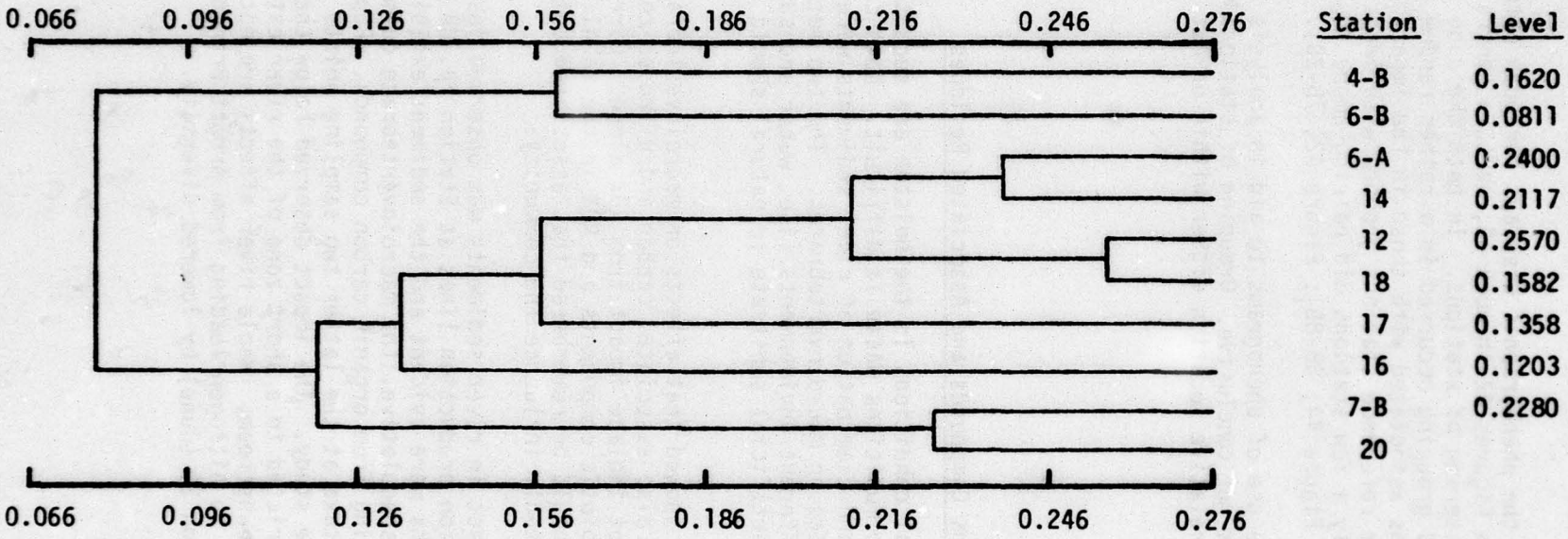
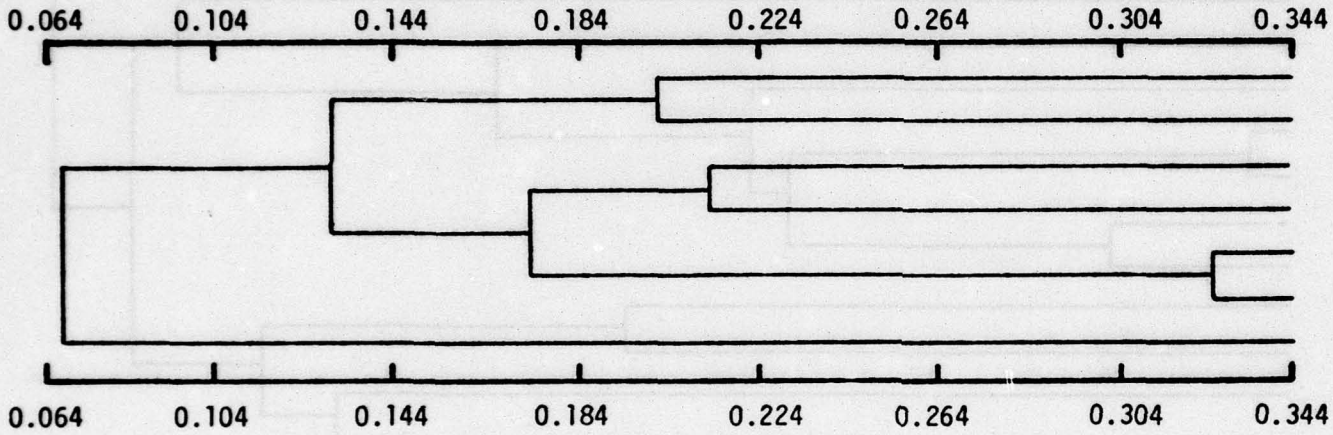
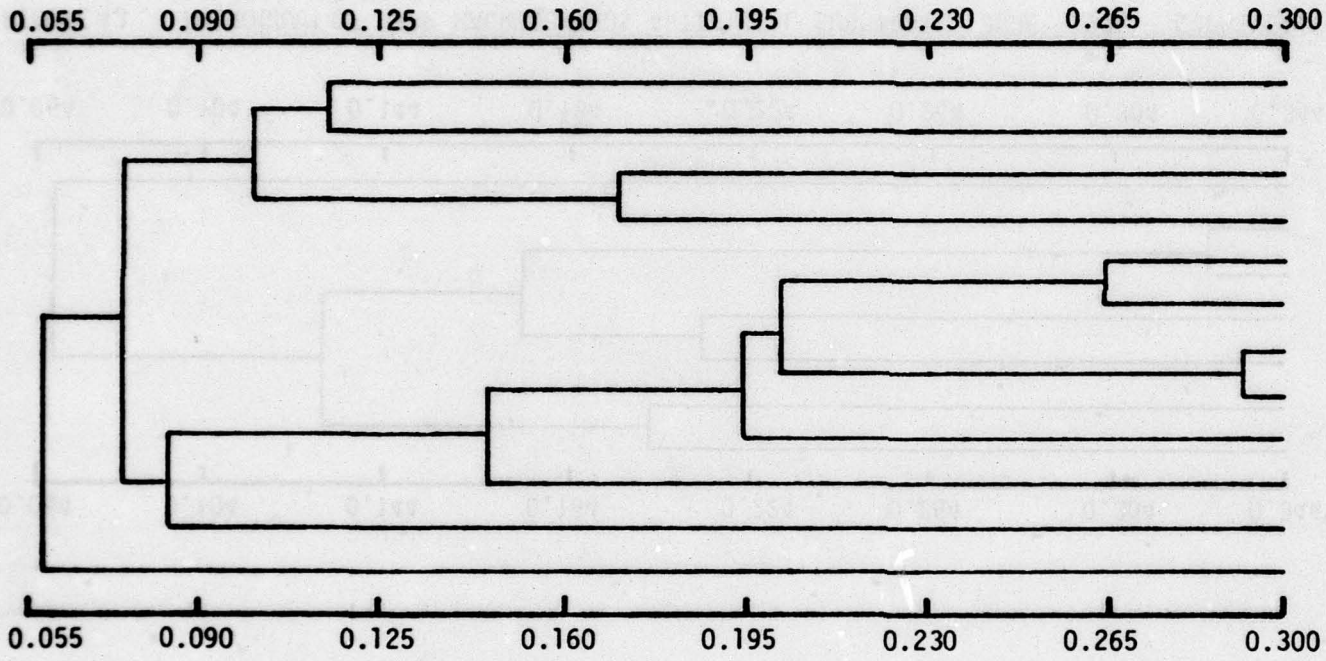


FIGURE 42 . PHENOGRAM OF HAAP MACROBENTHOS NATURAL SUBSTRATE, JUNE 1975. COPHENETIC CORRELATION COEFFICIENT, 0.809



Station	Level
6-A	0.2040
20	0.1335
6-B	0.2160
18	0.1772
12	0.3290
14	0.0718
17	

FIGURE 43. PHENOGRAM OF HAAP MACROBENTHOS ARTIFICIAL SUBSTRATE, JUNE 1975. COPHENETIC CORRELATION COEFFICIENT, 0.781



Station	Level
4-B	0.1140
7-B	0.1017
8-B	0.1710
8-B1	0.0750
6-A	0.2630
17	0.2005
12	0.2940
14	0.1945
18	0.1470
6-B	0.0838
20	0.0546
13	

FIGURE 44 . PHENOGRAM OF HAAP MACROBENTHOS NATURAL SUBSTRATE, AUGUST 1975. COPHENETIC CORRELATION COEFFICIENT, 0.830

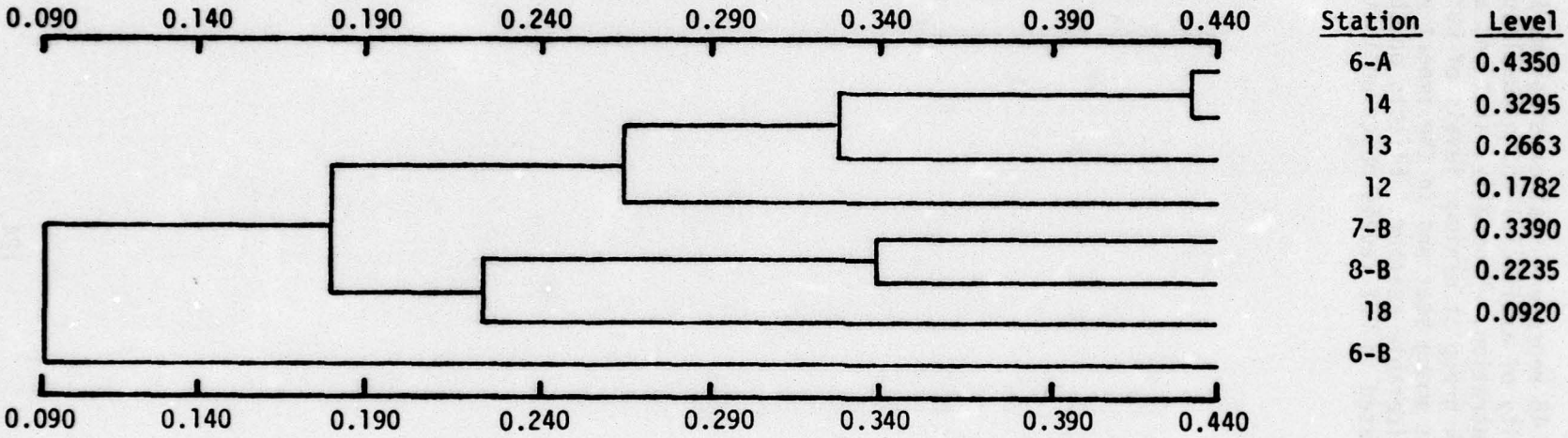


FIGURE 45 . PHENOGRAM OF HAAP MACROBENTHOS ARTIFICIAL SUBSTRATE, AUGUST 1975. COPHENETIC CORRELATION COEFFICIENT, 0.873

Figures 46, 47, and 48 represent scatter diagrams in which population, number of taxa, and diversity of artificial and natural substrates are plotted as a function of RDX concentration. Generally, stations above the effluent lines and on the south bank group at minimum levels of RDX (<0.005 mg/l). No clear trends are evident among stations in the impact zone along the north bank as the data show considerable scatter. Effects on the macroinvertebrate community cannot be correlated to RDX levels observed in the field studies.

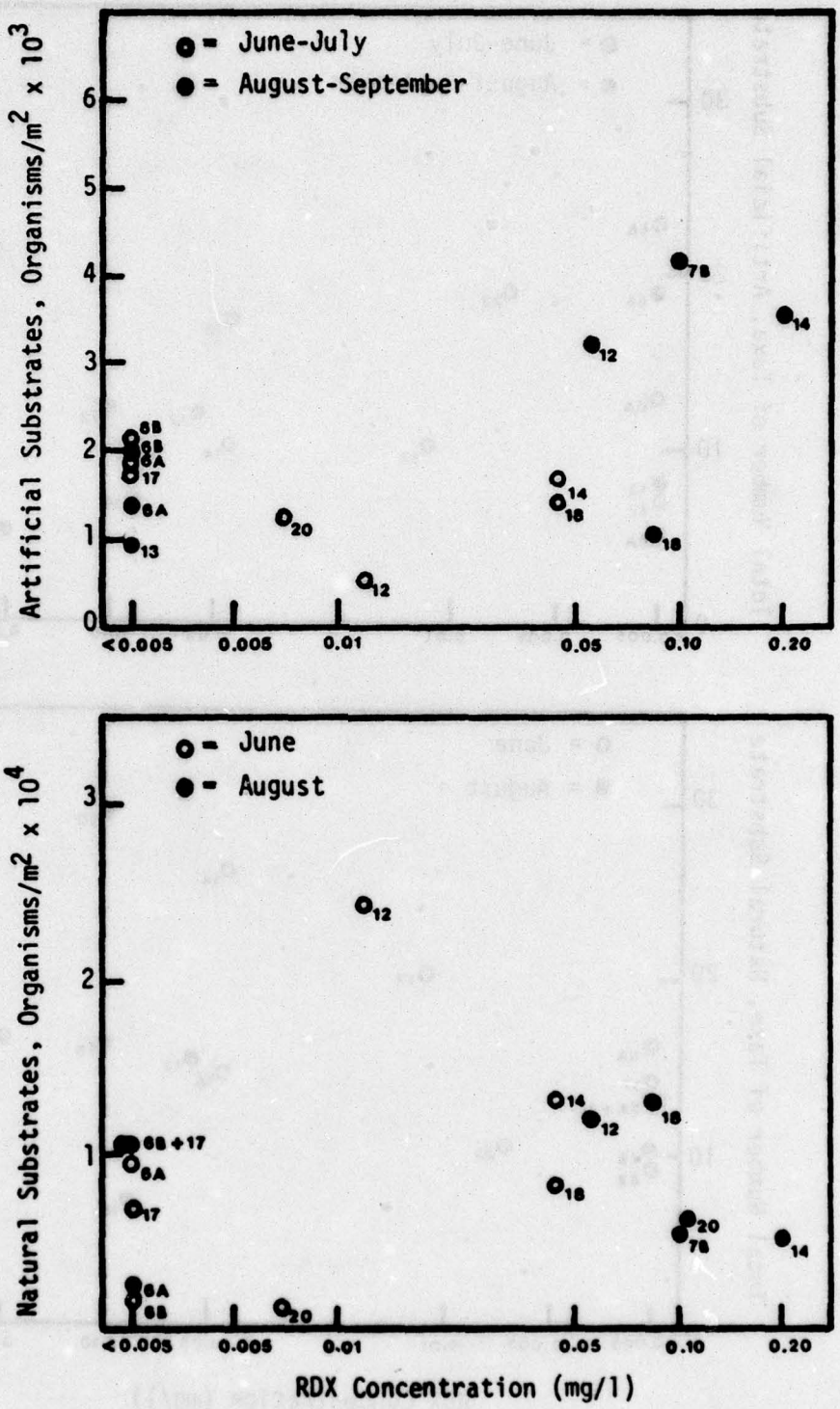


FIGURE 46. RDX CONCENTRATION VS MACROINVERTEBRATE DENSITY ON NATURAL AND ARTIFICIAL SUBSTRATES IN THE HOLSTON RIVER, JUNE - SEPTEMBER, 1975.

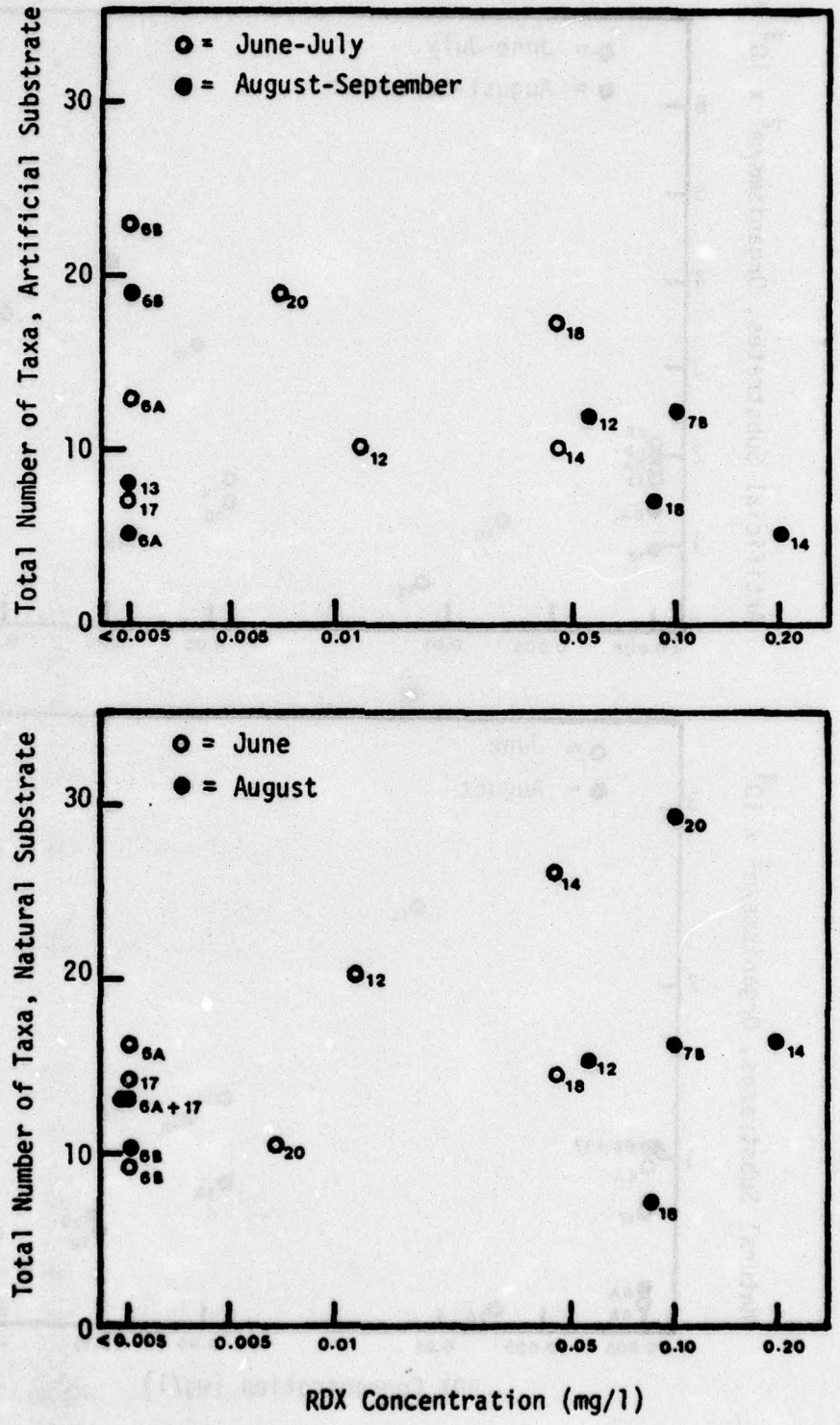


FIGURE 47. RDX CONCENTRATION VS NUMBER OF TAXA ON NATURAL AND ARTIFICIAL SUBSTRATES IN THE HOLSTON RIVER, JUNE - SEPTEMBER, 1975.

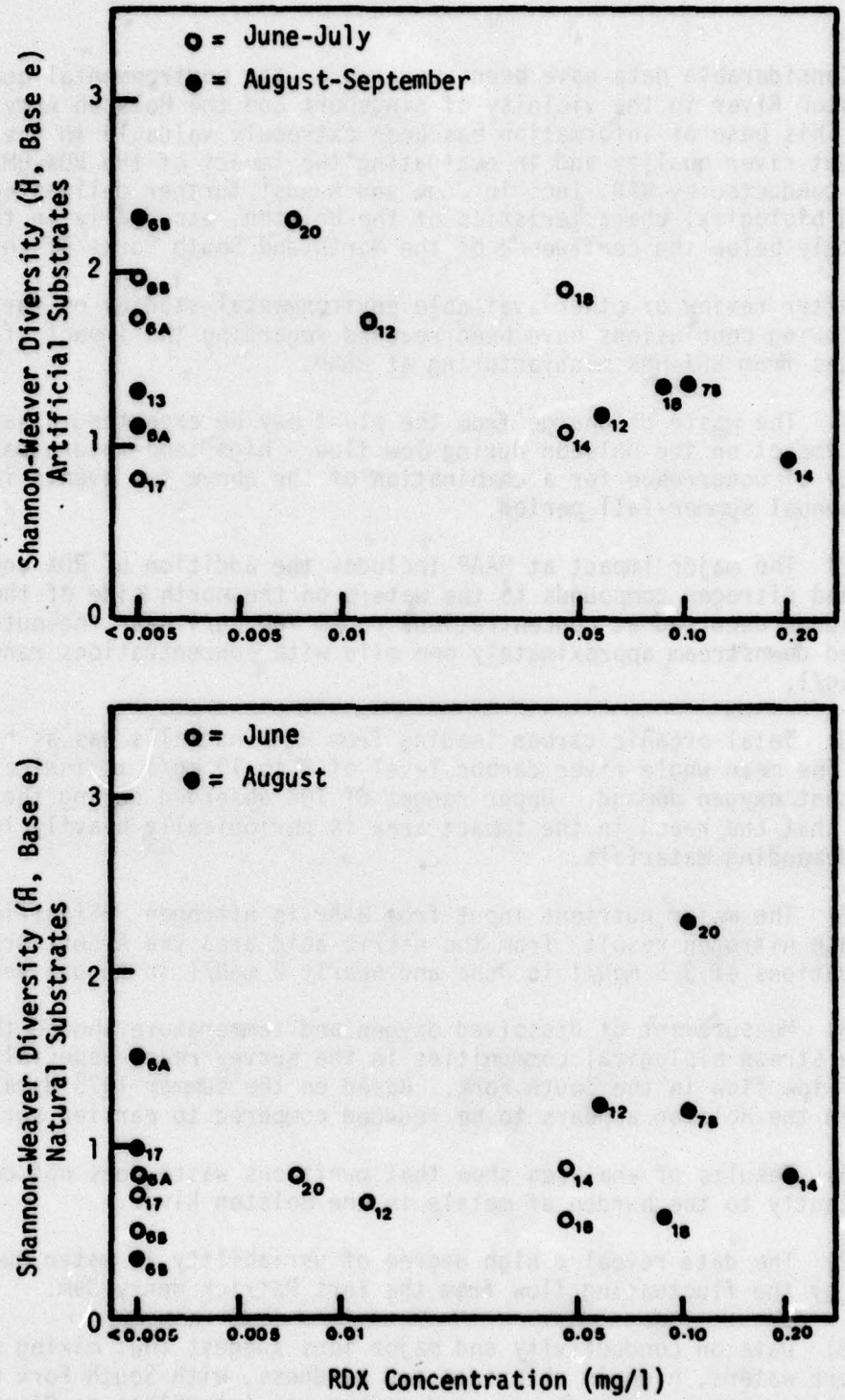


FIGURE 48. RDX CONCENTRATION VS SHANNON-WEAVER DIVERSITY (BASE E) ON NATURAL AND ARTIFICIAL SUBSTRATES IN THE HOLSTON RIVER, JUNE - SEPTEMBER, 1975.

CONCLUSIONS

Considerable data have been acquired on the environmental quality of the Holston River in the vicinity of Kingsport and the Holston Army Ammunition Plant. This base of information has been extremely valuable in the assessment of present river quality and in evaluating the impact of the RDX-HMX facility. Studies conducted by WAR, Inc. in June and August further delineated the chemical and biological characteristics of the Holston, especially in the reach immediately below the confluence of the North and South Forks of the river.

After review of other available environmental studies on the Holston, the following conclusions have been reached regarding the impact of waste discharges from RDX-HMX manufacturing at HAAP.

1) The waste discharge from the plant may be expected to have its maximum impact on the Holston during low flow - high temperature periods. Frequency of occurrence for a combination of the above two events is limited to the annual summer-fall period.

2) The major impact at HAAP includes the addition of RDX and associated carbon and nitrogen compounds to the waters on the north side of the Holston. RDX residues occurred at concentrations up to 700 µg/l near the outfalls and persisted downstream approximately one mile with concentrations ranging from 0 - 70 µg/l.

3) Total organic carbon loading from HAAP outfalls was as high as 330 mgC/l. The mean whole river carbon level of 8 to 10 mg/l is indicative of significant oxygen demand. Upper ranges of TOC observed during the study suggest that the reach in the impact area is periodically heavily loaded by oxygen demanding materials.

4) The major nutrient input from HAAP is nitrogen. Significant amounts of nitrate nitrogen result from the nitric acid area via Arnott Branch. Concentrations of 3.5 mgN/l in June and nearly 9 mgN/l in August were observed.

5) Measurement of dissolved oxygen and temperature showed that low D.O. may stress biological communities in the survey reach especially during times of low flow in the South Fork. Based on the summer 1975 data, oxygen stress in the Holston appears to be reduced compared to earlier surveys.

6) Results of analyses show that munitions waste does not contribute significantly to the burden of metals in the Holston River.

7) The data reveal a high degree of variability in water quality created by the fluctuating flow from the Fort Patrick Henry Dam.

8) Data on conductivity and major ions suggest that mixing of the North Fork waters, high in chlorides and hardness, with South Fork waters, enriched in nitrogen, phosphorus, and carbon was incomplete to River Mile 138. Dispersion studies using Rhodamine WT show HAAP discharge confinement to the north bank.

9) Sediments on the north side of the river exhibited elevated TKN and COD which progressively increased downstream of the production line effluents. RDX was the major munitions component isolated from river water; TKN from sediments.

10) Effects of munitions effluents were noted in the periphyton in the immediate vicinity of the waste outfall. Significant increases in heterotrophic biomass and a concomitant reduction in chlorophyll-bearing species were noted. Reductions in species diversity and shifts in diatom species associations indicate community alterations from RDX and associated residues.

11) The macroinvertebrate community is dominated by oligochaetes especially in the immediate areas of the waste outfalls. Chironomids abundantly colonized artificial substrates and river sediments with Chironomus attenuatus and Psectrocladius sp. predominate. Impact of wastes from HAAP except in the outfall plume cannot be clearly defined.

12) Munitions waste loading from HAAP produces a highly variable RDX concentration ranging to 700 µgm/l through the impact area. Associated with RDX production are quantities of organic carbon (i.e. cyclohexanone) and nitrogen which affect aquatic life in the river.

At the present time with the data available, environmental effects of specific carbon and nitrogen compounds cannot be evaluated. These occur in sufficient concentrations to influence aquatic life in the river and it is probable that impact on the various biological forms results from a synergism of many substances in munitions waste. The results of these studies showed that community alteration in the periphyton could be detected in water containing RDX ranging as low as 20 µg/l. We do not conclude that RDX at this low level is the single responsible compound for change. Multiple factors are involved. Further assessment would be required under more controlled conditions to define other variables and their influence in regulating community structure in the Holston River. Based on conservative estimates, however, a no-effect range of 20 to 100 µg/l RDX is recommended for periphyton communities continuously exposed to effluent generated in the manufacturing of this compound.

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APPENDIX A

WATER QUALITY DATA
HOLSTON RIVER
VICINITY OF HAAP
JUNE AND AUGUST, 1975

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APPENDIX A-I

Analytical Methodology

Water Quality Appendix

Table A-1 lists the specific Standard Methods or EPA procedures used to characterize the background water quality. Metals, except for hardness (calcium and magnesium) were run by flame atomic absorption spectrophotometry on acidified water samples. The expected low concentrations indicated that extraction using ammonium 1-pyrrolidinedithiocarbamate (APDC) and methyl iso-butyl ketone (MIBK) (after Nix and Goodwin, 1970) would be necessary to gain the required sensitivity. Mercury was analyzed by cold vapor atomic absorption spectrophotometry.

The nutrient (nitrogen, phosphorus, and carbon) parameters measured were those usually used to characterize trophic state. These results were used to assess what, if any, factors might limit plant growth, whether biostimulatory effects might be expected; and, secondly, to determine what oxygen demands might result. Selection of these parameters was also keyed to those specific to munitions manufacture waste impacts.

In the case of the metal analyses run on the sediments, the digestate contained sufficiently high concentrations of metals to be run directly by flame atomic absorption spectrophotometry making MIBK-APDC extraction unnecessary. The sediment mercuries were analyzed employing cold vapor atomic absorption spectrophotometry after the digestion of a portion of sediment with aqua regia as described in EPA (1974).

Analytical procedures (Table A-1) utilized on the sediment samples came mostly from the Chemistry Laboratory Manual Bottom Sediments (EPA, 1969) with the exceptions of mercury (as described above) and total phosphorus. The total phosphorus procedure employed sulfuric acid-potassium persulfate digestion in an autoclave as specified in "Sludge Sediment Analyses" (EPA, Region IV, 1973).

Munitions Analysis

Samples for munitions analyses were collected in amber glass reagent bottles, which were pre-rinsed in acetone, and refrigerated until analysis, which consisted of extraction, concentration, and gas-liquid chromatography.

Extraction of Water Samples. A sample of 250 ml was measured into a clean 500 ml separatory funnel equipped with a Teflon stopcock. Seventy-five ml of ethyl acetate (pesticide grade) was added, the flask stoppered, and shaken for 2 to 3 minutes. The layers were allowed to separate and the lower (water) layer drained into a second 500 ml separatory funnel and again extracted with 50 ml ethyl acetate. The water layer was discarded. The extracts were combined and filtered through a plug of cotton previously

wetted with ethyl acetate. The separatory funnels were rinsed with an additional 10 ml of ethyl acetate and filtered through the cotton plug. The ethyl acetate was evaporated to a volume of 2.5 ml under reduced pressure with the flask temperature not exceeding 40°C.

Extraction of Sediment Samples. In order to dry the wet sediments 80 gm of sodium sulfate was added to 20 gm of wet sediment. This was then packed into a chromatographic column and extracted for one hour with ethyl acetate. The extraction was followed by evaporation of the ethyl acetate extract to a volume of 2.0 ml under the same conditions as described earlier. The one hour of extraction with ethyl acetate was proven to be sufficient by the fact that quantitative recovery of sediment samples spiked with 2,4-DNT, 2,6-DNT, α-TNT, RDX, and HMX was obtained.

Chromatography of Extracts. Samples were chromatographed on a 5 ft. x 1/8 in. glass column packed with 3 percent Dexsil 300 on 80/100 mesh Gas Chrom Q. A Varian Model 1840 Gas Chromatograph with electron capture (EC) and Thermionic (Alkali Flame Ionization Detector) (AFID) detectors was chosen. The readout was obtained by using a Varian Model 285 Electronic Integrator which was recorded permanently by a Beckman 1 mv, 20 inch scale recorder. Peak areas were automatically printed by the integrator. Electron capture was chosen as the prime detector with AFID as back-up and confirmation detector.

An alternate column used for confirmatory information was a 4 ft. x 1/8 in. glass column packed with 8 percent UCW 98 on 80/100 mesh Gas Chrom Q. Instrument conditions for both columns and detectors were:

Column temperature:	185°C isothermally
Injector temperature:	220°C
Detector temperature:	215°C
Carrier Gas:	Nitrogen @ 40 ml/min
Electrometer setting:	10^{-10} afs at 1 x attenuation into integrator with appropriate attenuation setting for recorder

Five microliter portions of standards and samples were injected. The peak heights, peak areas, and retention times were recorded for comparison.

Preparation of Standards. Purified standards of 2,4-Dinitrotoluene; 2,6 Dinitrotoluene, 1,3,5-Trinitrobenzene, 2,4,6-Trinitrotoluene (TNT), cyclotrimethylenetrinitramine (RDX), and cyclotetramethylenetetranitramine (HMX) were supplied by the Army Medical Research and Development Command.

Discussion of Procedure. Under test conditions, 2,4-DNT, 2,6-DNT, 2,4,6-TNT and RDX were adequately resolved by both Dexsil 300 and UCW 98 columns. However, 1,3,5-TNB and 2,4,6-TNT were not differentiated by the Dexsil column and only partially by the UCW 98 column; consequently, 1,3,5-TNB, if present, was combined with and reported as 2,4,6-TNT.

HMX could not be detected at all by gas-liquid chromatography methods, therefore, thin layer chromatography was used to screen for this compound. Standards and samples were spotted on Silica Gel 1B-2F plates. The plates were developed with ethyl acetate and visualized under shortwave (254 NM)

ultraviolet light, and, in addition, they were developed by spraying with Ethylenediamine in DMSO as the chromogenic reagent. Under these conditions, approximately 5 µg of HMX could be detected. By concentrating the extract to 0.5 ml, approximately 1 mg/l HMX could be detected.

Five µl injections of sample extracts and standards were first injected onto the Dexsil 300 column using the EC Detector. Peaks corresponding to standards were noted and the areas compared. Samples and standards were next injected onto UCW 98 column and like comparisons were made. Likewise, samples and standards were injected onto the Dexsil 300 column using the Thermionic or Alkali Flame Ionization Detector. Again, peaks corresponding to the standards were noted and the areas were compared. Sample peaks which did not elute at the same times as the standards on both sets of columns and detectors were rejected, and only those peaks confirmed on both sets were quantitated.

The AFID was used primarily for confirmation of the presence or absence of various compounds in the samples. However, results were calculated and compared with results from the EC detector. In most cases, quantitative results were comparable with both detectors. Where agreement was not within limits of ± 10 percent, additional injections were made until agreement could be obtained within these limits, or it was determined that substrate interference effected response from one or the other of the detectors. This was normally determined by spiking the sample with the appropriate standard and noting the recovery.

Recovery Studies. Initial recovery studies were made by the addition of standards to tap water and then carrying through the entire extraction, concentration, and gas chromatographic procedures, as previously outlined.

Three levels of spiking were used, as follows:

Component	Quantity Added	Quantity Recovered	Percent Recovery
2,4-DNT	1.00 mg/l	0.95 mg/l	95
	5.00 mg/l	4.80 mg/l	96
	10.00 mg/l	10.05 mg/l	101
2,6-DNT	1.00 mg/l	0.93 mg/l	93
	5.00 mg/l	4.95 mg/l	99
	10.00 mg/l	10.2 mg/l	102
2,4,6-TNT	1.00 mg/l	0.96 mg/l	96
	5.00 mg/l	5.15 mg/l	103
	10.00 mg/l	9.80 mg/l	98
RDX	1.00 mg/l	0.89 mg/l	89
	5.00 mg/l	4.6 mg/l	92
	10.00 mg/l	9.7 mg/l	97

Selected samples from the Holston River and from Lake Chickamauga, Tennessee, containing low levels or no munitions residues were spiked with corresponding low levels of RDX and TNT to assess recovery under these conditions. Results of these experiments were:

Sample No.	Residual Component & Concentration		Component Added & Concentration		Percent Recovery
B-41	2,4-DNT	19 µg/l	2,4,6-TNT	4 µg/l	94
				8 µg/l	92
				10 µg/l	98
B-59	None	--	2,4,6-TNT	1 µg/l	89
				2 µg/l	93
				3 µg/l	96
B-39	None	--	2,4,6-TNT	2 µg/l	90
				4 µg/l	93
				6 µg/l	96
B-41	2,4-DNT	19 µg/l	RDX	4 µg/l	80
				8 µg/l	75
				10 µg/l	100
B-59	None	--	RDX	1 µg/l	105
				2 µg/l	89
				3 µg/l	86
B-39	None	--	RDX	2 µg/l	88
				4 µg/l	87
				6 µg/l	94

Recovery of TNT and its analogs by this procedure appears to be excellent, averaging more than 95 percent from tap water and 93 percent from spiked water samples. RDX recovery was not quite as good, averaging 93 percent from tap water and 89 percent from spiked water samples.

HMX was not detected in any of the water samples above the detection limit of 1 ppm; therefore, quantitation of recovery efficiencies were not performed on the water samples.

TABLE A-1

SUMMARY OF ROUTINE LABORATORY ANALYTICAL PROCEDURES
FOR WATER SAMPLES

Parameter	Procedure
Total Alkalinity	Standard Methods, 201: Potentiometric Titration, p. 370.
Chloride	Standard Methods, 112B: Mercuric Nitrate Method, p. 97
Total Hardness	Standard Methods, 112B: EDTA Titrimetric Method, p. 179.
Sulfate	Standard Methods, 156C: Turbidimetric Method, $BaCL_2$, p. 334.
Solids - Total Solids	Standard Methods, 148A: Gravimetric Method, p. 288.
Suspended Solids	Standard Methods, 148C: Gravimetric Method, p. 291.
Total Dissolved Solids	Standard Methods, 148B: Gravimetric Method, p. 290
Ammonia Nitrogen	EPA, STORET #00610: Distillation and Nesslerization, p. 159.
Total Kjeldahl Nitrogen	EPA, STORET #00625: Acid Digestion, Distillation, Nesslerization, p. 175.
Nitrite Nitrogen	EPA, STORET #00630: Automated Analyses, Diazotization, Sulfanilic Acid-Napthylamine Hydrochloride Method, p. 207.
Total Phosphorus	Standard Methods, 223C.III: Persulfate Digestion Method, p. 526. EPA, STORET #00671: Automated Colorimetric Ascorbic Acid Single Reagent Method, p. 256.
Total Organic Carbon	EPA, STORET #00680, Infrared CO_2 Detection, Carbon Analyzer, p. 236.
Chemical Oxygen Demand	EPA, STORET #00335, Low Level 0.025N $K_2Cr_2O_7$, p. 21.

EPA 1974, "Manual of Methods for Chemical Analysis of Water and Wastes."

Standard Methods for the Examination of Water and Wastewater, 13th Ed., 1971, APHA, AWWA, WPCF.

TABLE A-2

SUMMARY OF ROUTINE LABORATORY ANALYTICAL PROCEDURES
FOR SEDIMENT SAMPLES

Parameter	Procedure
Chemical Oxygen Demand	Bottom Sediments - Great Lakes: High Level 0.250N $K_2Cr_2O_7$, p. 5.
Total Kjeldahl Nitrogen	Bottom Sediments - Great Lakes: Acid Digestion, Distillation, and Titration with 0.02N H_2SO_4, p. 38.
Nitrate Nitrogen	Bottom Sediments - Great Lakes: Acid Digestion, p. 32. Standard Methods, 213B: Cadmium Reduction Method, p. 458.
Nitrite Nitrogen	Bottom Sediments - Great Lakes: Acid Digestion, p. 32. EPA, STORET #00630: Automated Analyses, Diazotization, Sulfanilic Acid-Napthylamine Hydrochloride Method, p.207.
Total Phosphorus	EPA, Region IV, "Sludge-Sediment Analyses," 1973: Sulfuric Acid-Persulfate Digestion using an Autoclave. EPA, STORET #00671: Automated Colorimetric Ascorbic Acid Single Reagent Method, p. 256.
Total Solids	Bottom Sediments - Great Lakes: Gravimetric Method, p. 85.
Total Volatile Solids	Bottom Sediments - Great Lakes: Gravimetric Method, p. 85.
Mercury	EPA, 1974: Aqua Regia Digestion, Potassium Permanganate Oxidation, and Cold Vapor Technique Atomic Absorption Spectrophotometry, p. 134.
Trace Metals (Cd, Cu, Cr, Fe, Pb, Mn, Ni, Zn)	Bottom Sediments - Great Lakes: Nitric Acid - Hydrogen Peroxide Digestion, p. 18. Atomic Absorption Spectrophotometry.

Chemistry Laboratory Manual Bottom Sediments, EPA 1969, compiled by Great Lakes Region Committee on Analytical Methods.

EPA 1974, "Manual of Methods for Chemical Analysis of Water and Wastes".

EPA, Region IV, Surveillance and Analysis Division, Chemical Services Branch, "Sludge-Sediment Analyses," June 7, 1973, mimeograph courtesy of James Finger, EPA, Region IV.

Standard Methods for the Examination of Water and Wastewater, 13th Ed., 1971, APHA, AWWA, WPCF.

APPENDIX A-II

Field Measurements of Water Quality in the Holston River

USGS River Mile 136-144

June 2-6, 1975
August 4-8, 1975

TABLE A-3

pH

Station	6/2/75 A.M.	6/2/75 P.M.	6/3/75 A.M.	6/3/75 P.M.	6/4/75 A.M.	6/4/75 P.M.	6/5/75 A.M.	6/5/75 P.M.	6/6/75 A.M.	6/6/75 P.M.	Median	Range
1	7.9	7.9	7.8	--	--	--	--	--	--	7.7	7.8	7.7-7.9
2	7.6	7.7	7.6	--	--	--	--	--	--	7.2	7.6	7.2-7.7
3	7.5	7.6	7.5	--	--	--	--	--	--	7.3	7.5	7.3-7.6
4	7.8	7.7	7.9	--	--	--	--	--	--	7.8	7.8	7.7-7.9
5	--	7.7	7.3	--	--	--	7.1	--	--	7.3	7.4	7.1-7.7
4B	--	--	--	--	--	--	--	--	--	--	--	--
6A	--	--	--	--	--	--	--	--	7.4	--	7.4	7.4
6	--	--	--	--	--	--	--	--	--	--	--	--
6B	--	--	--	--	--	--	--	--	7.5	--	7.5	7.5
7	--	5.6	5.9	--	--	--	6.9	--	--	7.3	6.4	5.6-7.3
8	--	--	--	--	--	--	6.5	--	--	--	6.5	6.5
13	--	--	--	--	--	--	--	--	--	--	--	--
14	--	--	--	--	--	--	--	--	--	--	--	--
9	--	--	--	--	--	--	--	--	--	--	--	--
15	--	--	--	--	--	--	7.5	--	--	--	7.5	7.5
16	--	--	--	--	--	--	7.8	--	--	--	7.8	7.8
11	--	--	--	--	--	--	--	--	--	--	--	--
17	--	--	--	--	--	--	7.7	--	7.4	--	7.6	7.4-7.7
18	--	--	--	--	--	--	7.7	--	7.4	--	7.6	7.4-7.7
10	--	7.6	--	7.7	--	--	7.2	--	--	7.5	7.5	7.2-7.7
19	--	--	--	--	--	--	7.2	--	--	--	7.2	7.2
20	--	--	--	--	--	--	7.0	--	--	--	7.0	7.0
12		7.7	7.5	--	--	--	--	--	--	--	7.6	7.5-7.7

TABLE A-4

pH

Station	8/4/75 A.M.	8/4/75 P.M.	8/5/75 A.M.	8/5/75 P.M.	8/6/76 A.M.	8/6/76 P.M.	8/7/75 A.M.	8/7/75 P.M.	8/8/75 A.M.	8/8/75 P.M.	Median	Range
1	--	--	--	--	--	--	--	--	--	--	--	--
2	--	--	--	--	--	--	--	--	--	--	--	--
3	--	7.4	--	7.3	7.2	--	7.1	--	--	7.3	7.3	7.1-7.4
4	--	7.9	--	7.8	7.4	--	7.5	7.8	7.5	8.2	7.7	7.4-8.2
5	7.0	--	--	7.2	7.1	--	--	7.0	7.0	--	7.1	7.0-7.2
4B	--	--	--	--	--	--	--	--	--	--	--	--
6A	--	7.6	7.2	--	7.2	--	7.1	--	7.1	--	7.2	7.1-7.6
6	--	--	--	--	--	--	--	--	--	--	--	--
6B	--	7.7	7.3	--	7.5	--	7.5	--	7.5	--	7.5	7.3-7.7
7	6.4	--	--	6.3	5.9	--	--	--	--	5.7	6.1	5.7-6.4
7B	--	7.6	7.4	--	7.5	--	7.2	--	7.3	--	7.4	7.2-7.6
8	6.8	--	6.8	--	--	6.9	--	6.3	--	7.0	6.8	6.3-7.0
13	--	7.6	7.1	--	7.3	--	7.1	--	7.2	--	7.3	7.1-7.6
14	--	7.5	--	7.3	7.3	--	7.3	--	7.5	--	7.4	7.3-7.5
9	--	--	--	--	--	--	--	--	--	--	--	--
15	--	--	--	--	--	--	--	--	--	--	--	--
16	--	7.7	7.4	--	--	7.4	7.3	--	7.5	--	7.5	7.3-7.7
11	--	--	--	--	--	--	--	--	--	--	--	--
17	--	7.6	--	7.3	--	7.3	7.3	--	7.4	--	7.4	7.3-7.6
18	--	7.4	--	7.3	--	7.4	7.3	--	7.5	--	7.4	7.3-7.5
10	7.5	--	--	8.4	8.2	--	--	8.2	--	8.1	8.1	7.5-8.4
19	--	--	--	--	--	--	--	--	--	--	--	--
20	--	7.7	--	7.3	--	--	7.5	--	7.6	--	7.5	7.3-7.7
12	--	7.7	--	7.2	--	--	--	7.3	7.5	--	7.4	7.2-7.7

TABLE A-5

Dissolved Oxygen (ppm)

Station	6/2/75 A.M.	6/2/75 P.M.	6/3/75 A.M.	6/3/75 P.M.	6/4/75 A.M.	6/4/75 P.M.	6/5/75 A.M.	6/5/75 P.M.	6/6/75 A.M.	6/6/75 P.M.	Mean	Range
1	11.2	--	8.8	--	--	8.5	--	--	--	9.2	9.4	8.5-11.2
2	--	9.2	7.8	--	--	8.3	--	--	--	8.5	8.5	7.8-9.2
3	--	8.8	6.7	--	--	8.4	--	--	--	8.6	8.1	6.7-8.8
4	9.0	--	8.3	--	--	8.8	--	--	--	8.9	8.8	8.3-9.0
5	--	--	--	--	--	--	7.0	--	--	--	7.0	7.0
4B	--	--	--	--	--	--	--	--	--	--	--	--
6A	--	--	--	9.5	--	--	--	9.3	7.7	--	8.8	7.7-9.5
6	--	8.8	--	9.0	--	--	--	--	--	--	8.9	8.8-9.0
6B	--	--	--	8.4	--	--	--	8.9	7.8	--	8.4	7.8-8.9
7	--	7.0	5.6	--	--	4.5	6.2	--	--	6.2	5.9	4.5-7.0
8	--	4.6	--	--	--	4.4	4.6	--	--	4.5	4.5	4.4-4.6
13	--	--	--	9.2	--	--	--	9.0	7.6	--	8.6	7.6-9.2
14	--	--	--	8.1	--	--	--	8.7	7.5	--	8.1	7.5-8.7
9	--	9.4	--	--	--	--	--	--	--	--	9.4	9.4
15	--	--	--	9.5	--	--	8.6	8.9	7.6	--	8.7	7.6-9.5
16	--	--	--	8.4	--	--	8.6	8.7	7.3	--	8.3	7.3-8.7
11	--	9.1	--	--	--	--	--	--	--	--	9.1	9.1
17	--	--	--	8.8	--	--	8.7	8.4	7.7	--	8.4	7.7-8.8
18	--	--	--	8.1	--	--	8.4	8.4	7.3	--	8.1	7.3-8.4
10	8.0	--	--	8.2	--	7.2	7.7	--	--	8.0	7.8	7.2-8.2
19	--	--	--	--	--	--	7.6	--	--	--	7.6	7.6
20	--	--	--	--	--	--	6.9	--	--	--	6.9	6.9
12	7.8	--	--	--	--	--	--	--	--	--	7.8	7.8

TABLE A-6

Dissolved Oxygen (ppm)

Station	8/4/75		8/5/75		8/6/75		8/7/75		8/8/75		Mean	Range
	A.M.	P.M.	A.M.	P.M.	A.M.	P.M.	A.M.	P.M.	A.M.	P.M.		
1	--	--	--	--	--	--	--	--	--	--	--	--
2	--	--	--	--	--	--	--	--	--	--	--	--
3	--	--	--	6.9	4.5	--	2.0	--	--	6.5	5.0	2.0-6.9
4	--	--	--	8.0	6.8	--	6.9	8.8	6.8	9.8	7.9	6.8-9.8
5	1.5	--	--	5.6	3.5	--	--	2.8	3.5	--	3.4	1.5-5.6
4B	--	--	5.4	--	--	--	--	--	--	--	5.4	5.4
6A	--	--	4.4	--	3.6	--	3.3	--	4.3	--	4.0	3.3-4.4
6	--	--	--	--	--	--	--	--	--	--	--	--
6B	--	--	5.0	--	6.2	--	5.9	--	6.2	--	5.8	5.0-6.2
7	4.0	--	--	3.4	2.8	--	--	--	--	3.5	3.4	2.8-4.0
7B	--	--	5.5	--	6.2	--	5.0	--	4.8	--	5.4	4.8-6.2
8	4.0	--	--	--	4.0	3.3	--	4.5	--	4.7	4.1	3.3-4.7
13	--	7.6	4.6	--	4.4	--	3.2	--	4.6	--	4.9	3.2-7.6
14	--	6.2	--	5.0	6.0	--	5.4	--	6.2	--	5.8	5.0-6.2
9	--	--	--	--	--	--	--	--	--	--	--	--
15	--	--	--	--	--	--	--	--	--	--	--	--
16	--	7.1	4.7	--	--	5.6	5.2	--	5.8	--	5.7	4.7-7.1
11	--	--	--	--	--	--	--	--	--	--	--	--
17	--	7.2	--	5.1	--	4.7	4.0	--	5.6	--	5.3	4.0-7.2
18	--	6.9	--	5.3	--	5.5	5.0	--	5.6	--	5.7	5.0-6.9
10	7.2	--	--	6.9	7.4	--	--	7.3	--	7.0	7.2	6.9-7.4
19	--	--	--	--	--	--	--	--	--	--	--	--
20	--	7.3	--	5.6	--	--	4.8	--	5.0	--	5.7	4.8-7.3
12	--	6.6	--	6.3	--	--	--	5.6	6.5	--	6.3	5.6-6.3

TABLE A-7

Temperature (°C)

Station	6/2/75 A.M.	6/2/75 P.M.	6/3/75 A.M.	6/3/75 P.M.	6/4/75 A.M.	6/4/75 P.M.	6/5/75 A.M.	6/5/75 P.M.	6/6/75 A.M.	6/6/75 P.M.	Mean	Range
1	19.9	17.0	15.0	--	--	17.0	--	16.3	--	--	17.0	15.0-19.9
2	18.0	18.0	19.0	--	--	19.0	--	--	--	19.0	18.6	18.0-19.0
3	18.0	18.0	18.8	--	--	19.5	--	--	--	18.3	18.5	18.0-19.5
4	21.0	24.0	20.0	--	--	23.3	--	--	--	23.0	22.3	20.0-24.0
5	--	18.0	--	20.5	--	17.8	18.5	--	--	18.0	18.6	17.8-20.5
4B	--	--	--	--	--	--	--	--	--	--	--	--
6A	--	--	--	18.5	--	--	--	18.0	17.5	--	18.0	17.5-18.5
6	--	19.0	--	18.5	--	--	--	--	--	--	18.8	17.0-19.0
6B	--	--	--	21.0	--	--	--	20.3	20.0	--	20.4	20.0-21.0
7	--	25.0	24.5	--	--	26.8	24.5	--	--	24.0	25.0	24.0-26.8
8	--	28.0	--	--	--	26.3	28.0	--	--	24.5	26.7	24.5-28.0
13	--	--	--	20.0	--	--	--	17.0	18.8	--	18.6	17.0-20.0
14	--	--	--	22.5	--	--	--	21.5	21.0	--	21.7	21.0-22.5
9	--	18.0	--	--	--	--	--	--	--	--	18.0	18.0
15	--	--	--	19.5	--	--	18.5	18.0	17.8	--	18.5	17.8-19.5
16	--	18.0	--	22.0	--	--	21.8	21.0	--	--	21.6	21.0-22.0
11	--		--	--	--	--	--	--	--	--	18.0	18.0
17	--	--	--	21.0	--	--	20.5	20.0	--	--	20.5	20.0-21.0
18	--	--	--	22.5	--	--	21.5	21.3	21.0	--	21.6	21.0-22.5
10	--	26.0	--	22.0	--	25.0	24.0	--	--	22.0	23.8	22.0-26.0
19	--	--	--	--	--	--	--	20.0	--	--	20.0	20.0
20	--	--	19.9	--	--	--	--	22.0	--	--	22.0	22.0
12		21.0	19.5	--	--	--	--	--	--	--	20.1	19.5-21.0

TABLE A-8

Temperature (°C)

Station	8/4/74 A.M.	8/4/74 P.M.	8/5/75 A.M.	8/5/75 P.M.	8/6/75 A.M.	8/6/75 P.M.	8/7/75 A.M.	8/7/75 P.M.	8/8/75 A.M.	8/8/75 P.M.	Mean	Range
1	--	--	--	--	--	--	--	--	--	--	--	--
2	--	--	--	--	--	--	--	--	--	--	--	--
3	--	--	--	21.8	22.3	--	23.2	--	--	22.3	22.4	21.8-23.2
4	--	--	--	29.0	23.4	--	23.1	25.1	23.2	26.0	25.0	23.1-29.0
5	23.8	--	--	23.0	22.0	--	--	25.1	20.8	--	23.0	20.8-25.1
4B	--	--	24.0	--	--	--	--	--	--	--	24.0	24.0
6A	--	--	23.0	--	23.3	--	23.0	--	22.5	--	23.0	22.5-23.3
6	--	--	--	--	--	--	--	--	--	--	--	--
6B	--	--	23.0	--	23.3	--	23.0	--	22.5	--	23.0	22.5-23.3
7	31.0	--	--	30.5	31.0	--	--	--	--	29.8	30.6	29.8-31.0
7B	--	--	23.5	--	23.3	--	23.5	--	23.0	--	23.3	23.0-23.5
8	30.5	--	--	--	30.5	31.0	--	29.7	--	29.0	30.1	29.0-31.0
13	--	19.5	20.2	--	22.0	--	21.3	--	20.0	--	20.6	19.5-22.0
14	--	25.5	--	26.0	22.0	--	23.1	--	23.0	--	23.9	22.0-26.0
9	--	--	--	--	--	--	--	--	--	--	--	--
15	--	--	--	--	--	--	--	--	--	--	--	--
16	--	21.5	23.0	--	--	24.0	23.0	--	22.5	--	22.8	21.5-24.0
11	--	--	--	--	--	--	--	--	--	--	--	--
17	--	20.2	--	24.1	--	24.0	22.0	--	21.0	--	22.3	20.2-24.1
18	--	22.0	--	25.0	--	24.0	23.0	--	22.5	--	23.3	22.0-25.0
10	26.0	--	--	28.2	25.5	--	--	28.0	--	27.0	26.9	25.5-28.2
19	--	--	--	--	--	--	--	--	--	--	--	--
20	--	22.0	--	26.1	--	--	24.2	--	24.0	--	24.1	22.0-26.1
12	--	22.0	--	24.1	--	--	--	21.5	20.5	--	22.0	20.5-24.1

TABLE A-9

Specific Conductance (μmhos/cm)

Station	6/2/75 A.M.	6/2/75 P.M.	6/3/75 A.M.	6/3/75 P.M.	6/4/75 A.M.	6/4/75 P.M.	6/5/75 A.M.	6/5/75 P.M.	6/6/75 A.M.	6/6/75 P.M.	Mean	Range
1	323	130	235	--	--	130	--	--	--	130	190	130-323
2	160	148	200	--	--	145	--	--	--	150	161	145-200
3	159	145	220	--	--	155	--	--	--	139	164	139-220
4	440	630	350	--	--	250	--	--	--	335	401	250-630
5	--	140	--	270	--	193	180	--	--	138	184	138-270
4B	--	--	--	--	--	--	--	--	--	--	--	--
6A	--	--	--	210	--	--	--	150	190	--	183	150-210
6	--	--	--	200	--	--	--	--	--	--	200	200
6B	--	--	--	290	--	--	--	210	250	--	250	210-290
7	--	245	--	280	--	270	210	--	--	200	241	200-280
8	--	--	--	--	--	210	210	--	--	212	211	210-212
13	--	--	--	255	--	--	--	150	182	--	196	150-255
14	--	--	--	335	--	--	--	250	250	--	278	250-335
9	--	--	--	--	--	--	--	--	--	--	--	--
15	--	--	--	220	--	--	160	145	195	--	180	145-220
16	--	--	--	320	--	--	270	220	245	--	264	220-320
11	--	--	--	--	--	--	--	--	--	--	--	--
17	--	--	--	260	--	--	220	185	220	--	221	185-260
18	--	--	--	330	--	--	275	240	250	--	274	240-330
10	240	--	--	800	--	230	215	--	--	230	343	215-800
19	--	--	--	--	--	--	205	--	--	--	205	205
20	--	--	--	--	--	--	300	--	--	--	300	300
12	300	230	--	--	--	--	--	--	--	--	265	230-300

TABLE A-10

Specific Conductance (μmhos/cm)

Station	8/4/75 A.M.	8/4/75 P.M.	8/5/75 A.M.	8/5/75 P.M.	8/6/76 A.M.	8/6/76 P.M.	8/7/75 A.M.	8/7/75 P.M.	8/8/75 A.M.	8/8/75 P.M.	Mean	Range
1	--	--	--	--	--	--	--	--	--	--	--	--
2	--	--	--	--	--	--	--	--	--	--	--	--
3	--	--	--	180	220	--	270	--	--	180	213	180-270
4	--	--	--	625	260	--	630	600	730	870	619	260-870
5	268	--	--	200	227	--	--	256	210	--	232	200-268
4B	--	--	341	--	--	--	--	--	--	--	341	341
6A	--	--	208	--	237	--	261	--	220	--	232	208-261
6	--	--	--	--	--	--	--	--	--	--	--	--
6B	--	--	335	--	255	--	500	--	600	--	423	255-600
7	300	--	--	253	265	--	--	--	--	286	276	253-300
8	295	--	--	--	300	308	--	302	--	270	295	270-308
13	--	165	205	--	222	--	295	--	235	--	224	165-295
14	--	260	--	358	222	--	480	--	470	--	358	222-480
9	--	--	--	--	--	--	--	--	--	--	--	--
15	--	--	--	--	--	--	--	--	--	--	--	--
16	--	198	300	--	--	273	480	--	490	--	348	198-490
11	--	--	--	--	--	--	--	--	--	--	--	--
17	--	167	--	309	--	275	400	--	370	--	304	167-400
18	--	181	--	350	--	273	--	465	470	--	348	181-470
10	280	--	--	370	368	--	--	370	--	318	341	280-370
19	--	--	--	--	--	--	--	--	--	--	--	--
20	--	195	--	335	--	--	405	--	387	--	331	195-405
12	--	200	--	281	--	--	--	335	300	--	279	200-335

APPENDIX A - III

Chemical Water Quality Data

in the Holston River

USGS River Mile 136-144

June 2-6, 1975
August 4-8, 1975

TABLE A- 11

ALKALINITY
($mgCaCO_3/l$)

Station	6/2/75	6/3/75	6/4/75	6/5/75	6/6/75	Mean	Standard Deviation
1	153/60	106	60	-	60	87.8	41.5
2	60/60	70	62	-	64	63.2	4.1
3	62/60	66	61	-	61	62	2.3
4	110/100	104	86	-	96	99.2	9.0
5	60	65	65	72	59	64.2	5.2
6	64	63	-	-	-	63.5	0.7
6A	-	-	66	62	101	76.3	21.5
6B	-	-	78	70	84	77.3	7.0
7	36	38	0	54	19	29.4	20.6
8	20	57	54	44	54	45.8	15.2
9	130	66	-	-	-	98	45.2
10	72	81	65	64	80	72.4	8.0
11	60	67	-	-	-	63.5	4.9
12	74	87/82	79	72	78	78.7	5.4
13	-	64	70/65	57	64	64	4.6
14	-	85	84/70	74	85	79.6	7.1
15	-	64	66	59/58	75	64.4	6.8
16	-	82	81	76/68	84	78.2	6.4
17	-	72	74	70/64	79	71.8	5.5
18	-	83	78	76/72	86	79	5.6
19	-	69	68	62/70	66	67	3.2
20	-	86	86	76/78	86	82.4	5.0

TABLE A-12

ALKALINITY
(mg $CaCO_3$/l)

Station	8/4/75	8/5/75	8/6/75	8/7/75	8/8/75	Mean	Standard Deviation
3	62	62	72	74	80	70.0	7.9
4	88	87	70	88/90	86/83	84.6	6.8
5	73	64	70	76	65	69.6	5.1
6A	68	63	72	74	67	68.8	4.3
6B	68	64	70	82	80	72.8	7.8
7	47	39	42	69	30	45.4	15
7B	65	65	69	77	71	69.4	5.0
8	63	-	65/60	40	63	58.2	10
10	74	75	90	78	81	79.6	6.4
12	69	71	68	77	74	71.8	3.7
13	68	63	71	75	69	69.2	4.4
14	72	74	67	77	81	74.2	5.3
16	67	72	72	80	79	74.0	5.4
17	66	69	73	78	80	73.2	5.9
18	67	73	71	80	81	74.4	6.0
20	65	65	75	76	76	71.4	5.9

TABLE A- 13

TOTAL HARDNESS
($mgCaCO_3/l$)

Station	6/2/75	6/3/75	6/4/75	6/5/75	6/6/75	Mean	Standard Deviation
1	188/73.0	128	70.0	-	66.0	105	52.9
2	82.0/79.0	82.0	79.0	-	78.0	80.0	1.9
3	78.0/74.0	85.0	74.0	-	68.0	75.8	6.3
4	160/170	148	108	-	134	144	24.2
5	74.0	90.0	82.0	80.0	68.0	78.8	8.3
6	84.0	77.0	-	-	-	80.5	4.9
6A	-	-	82.0	75.0	90.0	82.3	7.5
6B	-	-	106	65.0	104	91.7	23.1
7	106	92.0	116	92.0	86.0	98.4	12.3
8	100	95.0	94.0	82.0	94.0	93.0	6.6
9	80.0	82.0	-	-	-	81.0	1.4
10	100	100	95.0	88.0	98.0	96.2	5.0
11	78.0	84.0	-	-	-	81.0	4.2
12	106	119/116	106	88.0	97.0	105	11.6
13	-	77.0	86.0/75.0	76.0	79.0	78.6	4.4
14	-	114	107/88.0	100	106	103	9.7
15	-	78.0	84.0	74.0/72.0	92.0	80.0	8.1
16	-	114	102	101/88.0	108	103	9.7
17	-	92.0	95.0	91.0/78.0	98.0	90.8	7.7
18	-	114	106	102/92.0	110	105	8.4
19	-	84.0	88.0	74.0/84.0	82.0	82.4	5.2
20	-	132	112	102/108	106	112	11.7

TABLE A-14

TOTAL HARDNESS
(mg $CaCO_3$/l)

Station	8/4/75	8/5/75	8/6/75	8/7/75	8/8/75	Mean	Standard Deviation
3	73.0	77.0	-	105	-	85.0	17.4
4	171	179	-	162	-	171	8.5
5	101	81.0	-	96.0	-	92.7	10.4
6A	83.0	84.0	-	108	-	91.7	14.2
6B	90.0	122	-	150	-	121	30.0
7	101	92.0	-	112	-	102	10.0
7B	85.0	95.0	-	-	-	90.0	7.1
8	102	-	-	109	-	106	4.9
10	102	93.0	-	111	-	102	9.0
12	84.0	102	-	117	-	101	16.5
13	77.0	90.0	-	106	-	91.0	14.5
14	96.0	123	-	141	-	120	22.6
16	84.0	113	-	143	-	113	29.5
17	83.0	110	-	134	-	109	25.5
18	86.0	120	-	144	-	117	29.1
20	85.0	111	-	135	-	110	25.0

TABLE A-15

CHLORIDE
(mg Cl/l)

Station	6/2/75	6/3/75	6/4/75	6/5/75	6/6/75	Mean	Standard Deviation
1	5.0/4.0	4.5	2.0	-	3.5	3.8	1.2
2	6.5/4.0	5.5	3.5	-	2.5	4.4	1.6
3	4.5/6.0	9.0	4.5	-	3.0	5.4	2.3
4	93.5/107	43.0	20.0	-	39.5	60.7	37.5
5	3.0	9.5	5.0	7.0	2.5	5.4	2.9
6	13.0	6.0		-	-	9.5	4.9
6A	-	-	5.0	3.5	3.0	3.8	1.0
6B	-	-	21.0	18.0	17.0	18.7	2.1
7	9.0	10.0	10.0	8.5	8.0	9.1	0.9
8	10.0	8.5	23.5	8.0	9.0	11.8	6.6
9	3.0	8.0		-	-	5.5	3.5
10	6.0	11.0	9.0	6.0	5.0	7.4	2.5
11	5.50	9.50		-	-	7.50	2.9
12	23.0	32.5/28.5	27.0	18.0	12.0	23.5	7.6
13	-	5.0	6.5/4.0	5.5	7.5	5.7	1.4
14	-	30.0	22.0/10.0	29.0	19.5	22.1	8.1
15	-	5.0	5.5	5.0/3.0	6.5	5.0	1.3
16	-	27.5	21.0	27.0/20.0	18.0	22.7	4.3
17	-	20.0	18.9	20.0/11.5	13.0	16.5	4.0
18	-	23.5	23.0	33.5/25.0	20.5	25.1	4.9
19	-	8.5	12.0	4.0/7.5	4.5	7.3	3.3
20	-	33.5	26.0	28.0/32.5	16.0	27.2	7.0

TABLE A- 16

CHLORIDE
(mg Cl/l)

Station	8/4/75	8/5/75	8/6/75	8/7/75	8/8/75	Mean	Standard Deviation
3	4.5	5.0	-	11.5	-	7.0	3.9
4	99.5	108	-	120/105	-	108	8.7
5	13.5	6.5	-	10.0	-	10.0	3.5
6A	4.0	10.5	-	42.5	-	19.0	20.6
6B	13.5	45.0	-	106	-	54.8	47
7	14.0	11.5	-	13.5	-	13.0	1.3
7B	12.5	16.0	-	-	-	14.3	2.5
8	12.0	-	-	25.5	-	18.8	9.5
10	13.5	9.5	-	12.0	-	11.7	2.0
12	10.5	24.0	-	59.0	-	31.2	25
13	6.0	13.0	-	30.0	-	16.3	12.3
14	17.0	39.5	-	76.0	-	44.2	29.8
16	16.5	35.5	-	85.5	-	45.8	35.6
17	8.0	30.5	-	60.0	-	32.8	26.1
18	13.5	43.5	-	79.5	-	45.5	33.0
20	11.5	35.5	-	45.5	-	30.8	17.5

TABLE A-17

SULFATE
(mg SO_4/l)

Station	6/3/75	6/5/75	Mean	8/4/75	8/5/75	Mean
1	19.1	-	19.1	-	-	-
2	17.0	-	17.0	-	-	-
3	31.0	-	31.0	14.9	19.7	17.3
4	13.6	-	13.6	14.6	14.5	14.6
5	46.8	26.1	36.5	40.5	29.4	35.0
6	13.7	-	13.7	-	-	-
6A	-	17.4	17.4	21.5	28.0	24.8
6B	-	14.2	14.2	11.0	22.8	16.9
7	35.0	29.2	32.1	43.2	30.4	36.8
7B	-	-	-	10.5	30.7	20.6
8	27.6	26.7	27.2	43.5	-	43.5
9	27.6	-	27.6	-	-	-
10	37.2	21.5	29.4	40.5	33.8	37.2
11	23.9	-	23.9	-	-	-
12	20.9	17.8	19.4	13.3	30.3	21.8
13	18.0	19.0	18.5	12.0	29.7	20.9
14	16.6	16.3	16.5	22.5	33.0	27.8
15	19.7	21.4/17.3	19.5	-	-	-
16	16.8	17.6/13.3	15.9	15.9	24.8	20.4
17	16.2	18.6/16.0	16.9	7.3	31.3	19.3
18	16.3	18.0/14.1	16.1	13.3	30.3	21.8
19	27.1	29.2/20.2	25.5	-	-	-
20	28.5	23.6/16.3	22.8	15.3	34.0	24.7

TABLE A- 18

TOTAL DISSOLVED SOLIDS
(mg/l)

Station	6/2/75	6/3/75	6/4/75	6/5/75	6/6/75	Mean	Standard Deviation
1	257/105	161	100	-	108	146	67
2	122/117	117	114	-	97	113	9.6
3	107/116	132	119	-	105	116	11
4	314/425	255	175	-	208	275	99
5	108	159	139	138	123	133	19
6	144	244	-	-	-	194	71
6A	-	-	110	73	166	116	47
6B	-	-	175	135	159	156	20
7	193	165	237	150	183	186	33
8	218	124	141	149	258	178	57
9	111	134	-	-	-	122	16
10	137	202	146	144	170	160	27
11	97	100	-	-	-	99	2
12	170	208/75	181	157	159	158	45
13	-	129	130/107	104	155	125	21
14	-	172	165/106	188	202	167	37
15	-	118	124	112/115	163	126	21
16	-	168	169	180/150	196	173	17
17	-	138	162	142/122	171	147	20
18	-	200	176	186/161	204	185	18
19	-	202	198	111/127	142	156	42
20	-	109	116	179/203	166	155	41

TABLE A-19

TOTAL DISSOLVED SOLIDS
(mg/l)

Station	8/4/75	8/5/75	8/6/75	8/7/75	8/8/75	Mean	Standard Deviation
3	106	112	124	296	222	172	84
4	400	392	132	464/424	503/576	413	140
5	168	118	110	222	212	166	52
6A	112	144	106	-	168	133	29
6B	130	228	98	422	439	263	160
7	162	180	82	254	222	180	66
7B	128	174	156	316	308	216	89
8	174	-	118/136	230	189	169	44
10	254	206	202	348	318	266	66
12	142	190	108	268	239	189	66
13	108	138	128	214	200	158	47
14	168	234	96	364	388	250	125
16	164	216	164	358	-	226	92
17	118	210	120	280	290	204	83
18	150	230	96	382	-	215	124
20	140	208	136	290	316	218	83

TABLE A- 20

SUSPENDED SOLIDS
(mg/1)

Station	6/2/75	6/3/75	6/4/75	6/5/75	6/6/75	Mean	Standard Deviation
1	9/6	7	20	-	8	10	6
2	19/7	10	5	-	12	11	6
3	28/8	16	21	-	12	17	8
4	18/44	41	26	-	18	29	12
5	21	17	5	1	9	11	8
6	11	32	-		-	22	15
6A	-	-	6	7	23	12	10
6B	-	-	19	16	20	18	2
7	16	28	28	10	13	19	8
8	15	18	16	21	25	19	4
9	16	17	-	-	-	17	1
10	5	14	14	7	31	14	10
11	9	25	-	-	-	17	11
12	11	30/50	22	7	20	23	15
13	-	16	4/14	6	14	11	5
14	-	47	52/23	9	23	31	18
15	-	20	13	2/8	26	14	9
16	-	50	19	9/8	4	18	19
17	-	33	15	19/17	17	20	7
18	-	52	15	3/10	13	19	19
19	-	20	10	11/4	33	16	11
20	-	47	12	5/7	16	17	17

TABLE A-21

SUSPENDED SOLIDS
(mg/l)

Station	8/4/75	8/5/75	8/6/75	8/7/75	8/8/75	Mean	Standard Deviation
3	14	4	150	6	8	36	64
4	14	4	356	38/22	29/19	69	127
5	16	16	104	6	<2	28	43
6A	32	6	96	-	6	35	42
6B	42	2	258	2.6	2.3	61	111
7	24	10	56	12	8	22	20
7B	36	4	200	40	8	58	81
8	12	-	63/30	22	9	27	22
10	24	4	66	6	6	21	26
12	28	2	172	6	5	43	73
13	44	4	142	4	4	40	60
14	26	12	284	24	6	70	120
16	6	<2	174	18	-	50	83
17	30	4	146	12	6	40	60
18	28	6	186	16	-	59	85
20	30	6	164	16	4	44	68

TABLE A-22

TOTAL SOLIDS
(mg/l)

Station	6/2/75	6/3/75	6/4/75	6/5/75	6/6/75	Mean	Standard Deviation
1	270/110	170	120	-	120	158	67
2	140/120	130	120	-	110	124	11
3	140/120	150	140	-	120	134	13
4	330/470	300	200	-	230	306	105
5	130	180	140	140	130	144	21
6	160	280	-	-	-	220	85
6A	-	-	120	80	190	130	56
6B	-	-	190	150	180	173	21
7	210	190	270	160	200	206	40
8	230	140	160	170	280	196	58
9	130	150	-	-	-	140	14
10	140	220	160	150	200	174	34
11	110	130	-	-	-	120	14
12	180	240/130	200	160	180	182	37
13	-	150	130/120	110	170	136	24
14	-	220	220/130	200	230	200	41
15	-	140	140	110/120	190	140	31
16	-	220	190	190/160	200	192	22
17	-	170	180	160/140	190	168	19
18	-	250	190	190/170	220	204	31
19	-	220	210	120/130	180	172	45
20	-	160	130	180/210	180	172	30

TABLE A-23

TOTAL SOLIDS
(mg/l)

Station	8/4/75	8/5/75	8/6/75	8/7/75	8/8/75	Mean	Standard Deviation
3	120	116	274	302	230	208	86
4	414	396	488	502/446	532/595	482	70
5	184	134	214	228	212	194	37
6A	144	150	202	-	174	168	26
6B	172	230	356	448	462	334	129
7	186	190	138	266	230	202	48
7B	164	178	356	356	316	274	96
8	186	-	180/166	252	198	196	33
10	278	210	268	354	324	287	55
12	170	192	280	274	244	232	49
13	152	142	270	218	204	197	52
14	194	246	380	388	394	320	94
16	170	216	338	376	-	275	98
17	148	214	266	292	296	243	62
18	178	236	282	398	-	274	93
20	170	214	300	306	320	262	66

TABLE A- 24

TOTAL ORGANIC CARBON
(mg C/l)

Station	6/2/75	6/3/75	6/4/75	6/5/75	6/6/75	Mean	Standard Deviation
1	8.5/5.3	7	6	-	16	8.6	4.3
2	7.3/8.5	7.5	8	-	8	7.9	0.5
3	8.1/8.0	12	8.5	-	8.5	9.0	1.7
4	10/6.8	8.5	7	-	11	8.7	1.8
5	7.0	15	11	8	10	10	3.1
6	6.3	4	-	-	-	5.2	1.6
6A	-	-	9.5	8.5	9	9.0	0.5
6B	-	-	9.5	8.5	9.5	9.2	0.6
7	44	41	88	21	53	49	25
8	330	40	170	130	59	146	116
9	5.5	9.5	-	-	-	7.5	2.8
10	8.5	11	13	10	17	12	3.3
11	5.7	10	-	-	-	7.9	3.0
12	6.5	9/5.5	10	7.5	11	8.3	2.1
13	-	7	4/8.5	13	11	8.7	3.5
14	-	16	8/9.5	7.5	9.5	10	3.4
15	-	7	9	8.5/9	10	8.7	1.1
16	-	13	8	7/8	10.5	9.3	2.4
17	-	9.5	9.5	9/9	9	9.2	0.3
18	-	9	10	7.5/14	10	10	2.4
19	-	8.5	8	9.5/9.5	10	9.1	0.8
20	-	9.5	9.5	8.5/9.5	10	9.4	0.5

TABLE A-25

TOTAL ORGANIC CARBON
(mg C/l)

Station	8/4/75	8/5/75	8/6/75	8/7/75	Mean	Standard Deviation
3	4.0	7.0	11.5	9.5	8.0	3.2
4	5.5	6.5	18.0	9.5/8.0	9.5	5.0
5	6.5	8.5	12.0	10.0	9.3	2.3
6A	6.5	7.5	13.0	9.5	9.1	2.9
6B	6.0	7.0	13.5	7.0	8.4	3.4
7	20.5	59	62.0	19.0	40.1	24
7B	4.0	10.0	15.0	12.5	10.4	4.7
8	16.5	-	36.0/28.0	93.0	43.4	34
10	7.0	13.0	13.5	15.0	12.1	3.5
12	8.0	7.5	12.0	9.0	9.1	2.0
13	5.5	8.0	10.0	10.5	8.5	2.3
14	9.5	9.5	14.5	10.0	10.9	2.4
16	6.0	9.0	14.5	11.0	10.1	3.6
17	3.0	9.5	14.5	9.5	9.1	4.7
18	4.0	10.5	15.5	8.5	10.0	4.8
20	5.0	12.0	14.0	12.0	10.8	3.9

TABLE A-26

CHEMICAL OXYGEN DEMAND
(mg/l)

Station	6/2/75	6/3/75	6/4/75	6/5/75	6/6/75	Mean	Standard Deviation
1	21/9.4	7.5	6.0	-	11	11	5.9
2	9.4	6.8	8.6	-	12.8	9.4	2.5
3	11/6.6	22	9.2	-	11	12	5.9
4	3.1/7.8	12	8.0	-	9.6	8.1	3.3
5	19	21	13	11	9.5	15	5.0
6	17	7.7	-	-	-	12	6.6
6A	-	-	16	9.5	15	14	3.5
6B	-	-	14	9.4	12	12	2.3
7	66	85	170	45	140	100	52
8	780	89	480	340	230	380	260
9	8.4	18	-	-	-	13	6.8
10	17	19	18	12	20	17	3.1
11	1.2	15	-	-	-	8.1	9.8
12	5.7	12/13	14	10	15	12	3.4
13	-	-	9.4/13	11	11	11	1.5
14	-	30	11/12	7.4	14	15	8.8
15	-	9.8	16	9.2/16	13	13	3.3
16	-	24	12	8.8/10	14	14	6.1
17	-	17	14	8.8/12	11	13	3.1
18	-	27	20	9.5/9.1	10	15	8.0
19	-	14	11	11/12	15	13	1.8
20	-	39	14	10/14	10	17	12

TABLE A- 27

CHEMICAL OXYGEN DEMAND
(mg/l)

Station	8/4/75	8/5/75	8/6/75	8/7/75	8/8/75	Mean	Standard Deviation
3	9.0	13	22	19	13	15	5.2
4	7.5	9.1	34	13/12	18/22	17	9.2
5	17	23	17	19	15	18	3.0
6A	24	15	22	15	13	18	4.9
6B	18	12	28	13	17	18	6.3
7	62	180	160	37	160	120	65
7B	27	19	27	23	26	24	3.4
8	78	-	69/75	260	80	112	83
10	17	32	31	32	29	28	6.4
12	19	9.8	24	12	10	15	6.3
13	17	19	25	18	14	19	4.0
14	51	36	41	22	20	34	13
16	35	17	26	14	17	22	8.6
17	50	19	27	14	13	25	15
18	24	13	26	16	17	19	5.5
20	25	26	26	17	20	23	4.1

TABLE A-28

TOTAL KJELDAHL NITROGEN
(mg N/l)

Station	6/2/75	6/3/75	6/4/75	6/5/75	6/6/75	Mean	Standard Deviation
1	0.49/5.67	0.38	0.54	-	0.19	1.45	2.36
2	0.69/0.68	0.64	1.06	-	0.04	0.62	0.37
3	0.62/0.42	1.31	1.00	-	0.57	0.78	0.36
4	0.43/0.48	1.07	0.10	-	0.45	0.51	0.35
5	0.75	1.91	1.57	1.50	0.16	1.18	0.71
6	0.58	1.34	-	-	-	0.96	0.54
6A	-	-	1.10	0.28	1.08	0.82	0.47
6B	-	-	0.50	0.38	0.54	0.47	0.08
7	6.03	1.36	0.92	1.57	0.22	2.02	2.30
8	2.32	1.52	4.28	2.16	1.62	2.38	1.12
9	3.75	1.73	-	-	-	2.74	1.43
10	1.24	2.92	1.32	1.42	0.89	1.56	0.79
11	0.73	1.29	-	-	-	1.01	0.40
12	0.48	0.61/0.87	1.56	1.25	0.07	0.81	0.54
13	-	0.70	1.46/1.20	1.67	-	1.26	0.42
14	-	0.69	0.70/0.86	1.06	0.87	0.84	0.15
15	-	1.21	1.24	1.64/1.31	1.38	1.36	0.17
16	-	0.60	0.70	1.05/1.05	0.22	0.72	0.35
17	-	0.80	0.52	0.65/0.30	0.54	0.56	0.18
18	-	0.72	0.46	0.40/0.37	0.40	0.47	0.14
19	-	1.41	1.34	1.62/1.90	0.89	1.43	0.37
20	-	0.76	1.15	0.72/1.18	-	0.95	0.25

TABLE A-29

TOTAL KJELDAHL NITROGEN
(mg N/l)

Station	8/4/75	8/5/75	8/6/75	8/7/75	8/8/75	Mean	Standard Deviation
3	1.29	0.74	1.41	1.92	0.96	1.26	0.45
4	0.42	0.57	3.12	0.54/0.53	0.81/0.84	1.98	0.96
5	0.81	1.71	2.52	1.88	1.41	1.67	0.63
6A	0.39	1.25	2.67	1.75	1.56	1.52	0.83
6B	2.55	0.86	1.62	1.11	1.05	1.44	0.68
7	2.10	1.20	1.44	1.76	1.86	1.67	0.35
7B	0.99	1.34	1.35	1.56	1.28	1.30	0.21
8	3.12	-	2.46/1.46	6.48	1.86	3.08	2.00
10	2.28	3.75	4.55	5.01	3.30	3.78	1.07
12	1.35	1.11	1.68	1.41	0.84	1.28	0.32
13	1.22	1.20	1.61	2.24	1.22	1.50	0.45
14	2.15	1.61	1.54	1.28	0.92	1.50	0.45
16	1.17	0.87	0.98	1.05	0.92	1.00	0.12
17	1.05	1.20	2.01	1.26	0.77	1.26	0.46
18	1.65	1.49	1.29	1.34	0.95	1.34	0.26
20	1.71	2.05	2.48	2.51	2.01	2.15	0.34

TABLE A-30

AMMONIA
(mg N/l)

Station	6/2/75	6/3/75	6/4/75	6/5/75	6/6/75	Mean	Standard Deviation
1	0.10/0.06	0.04	0.21	-	0.04	0.09	0.07
2	0.14/0.14	0.10	0.13	-	0.10	0.12	0.02
3	0.09/0.11	0.74	0.35	-	0.04	0.27	0.29
4	0.10/0.02	0.04	0.13	-	0.04	0.06	0.05
5	0.31	1.15	0.54	0.73	0.38	0.62	0.34
6	0.16	0.17	-	-	-	0.16	0.01
6A	-	-	0.62	0.38	0.52	0.51	0.12
6B	-	-	0.15	0.14	0.24	0.18	0.05
7	7.00	1.01	-	0.33	0.02	2.09	3.30
8	-	-	-	-	-	-	-
9	0.33	0.82	-	-	-	0.58	0.35
10	0.63	1.96	1.09	1.18	2.16	1.40	0.64
11	0.23	0.64	-	-	-	0.43	0.29
12	0.14	0.49/0.30	0.64	0.58	0.42	0.43	0.19
13	-	0.31	0.40/0.27	0.49	0.61	0.42	0.14
14	-	2.46	0.09/0.20	0.15	0.20	0.62	1.03
15	-	0.44	0.14	0.50/0.50	0.58	0.43	0.17
16	-	1.30	0.12	0.24/0.20	0.26	0.42	0.49
17	-	0.31	0.12	0.21/0.27	0.21	0.22	0.07
18	-	-	0.44	0.26/0.25	0.12	0.27	0.13
19	-	0.72	0.64	0.47/0.81	0.69	0.67	0.13
20	-	0.17	0.46	0.08/0.52	0.13	0.27	0.20

TABLE A-31

AMMONIA
(mg N/l)

Station	8/4/75	8/5/75	8/6/75	8/7/75	8/8/75	Mean	Standard Deviation
3	-	0.32	0.48	1.10	0.26	0.54	0.38
4	0.12	0.10	0.11	0.13/0.09	0.06/0.09	0.10	0.02
5	0.10	0.84	0.92	1.12	0.94	0.78	0.40
6A	0.42	0.83	0.89	1.24	0.83	0.84	0.29
6B	0.20	0.54	0.32	0.40	0.29	0.35	0.13
7	<0.02	-	<0.02	1.74	2.04	0.95	1.10
7B	<0.02	0.94	0.26	1.23	0.83	0.65	0.51
8	0.30	-	0.14/-	-	-	0.22	0.11
10	1.46	4.75	-	4.55	3.48	3.56	1.51
12	0.52	0.75	0.58	0.77	0.60	0.64	0.11
13	0.39	0.67	0.58	1.16	0.70	0.70	0.28
14	-	0.28	0.21	0.54	0.70	0.43	0.23
16	0.30	0.65	0.34	0.56	0.45	0.46	0.15
17	0.25	0.79	0.52	0.73	0.49	0.56	0.21
18	0.32	0.82	0.19	0.54	0.50	0.47	0.24
20	0.32	1.70	0.09	2.02	2.05	1.24	0.95

TABLE A-32

NITRITE
(mg N /l)

Station	6/2/75	6/3/75	6/4/75	6/6/75	Mean	Average	Standard Deviation
1	0.023/0.011	0.015	0.008	-	0.009	0.013	0.006
2	0.014/0.013	0.016	0.008	-	0.009	0.012	0.003
3	0.013/0.013	0.015	0.009	-	0.009	0.012	0.003
4	0.015/0.013	0.018	0.011	-	0.010	0.013	0.003
5	0.014	0.014	0.009	0.033	0.008	0.016	0.010
6	0.014	0.014	-	-	-	0.014	0
6A	-	-	0.009	0.009	0.013	0.011	0.002
6B	-	-	0.011	0.008	0.011	0.010	0.002
7	0.043	0.110	0.069	0.009	0.022	0.050	0.040
8	0.093	0.071	0.046	0.026	0.064	0.060	0.025
9	0.014	0.015	-	-	-	0.015	0.001
10	0.078	1.11	0.044	0.046	0.398	0.335	0.45
11	0.014	0.015	-	-	-	0.015	0.001
12	0.017	0.024/0.032	0.017	0.009	0.013	0.019	0.008
13	-	0.012	0.010/0.009	0.009	0.010	0.010	0.001
14	-	0.018	0.011/0.010	0.009	0.011	0.012	0.004
15	-	0.014	0.009	0.009/0.009	0.013	0.011	0.002
16	-	0.017	0.012	0.009/0.009	0.011	0.012	0.003
17	-	0.015	0.010	0.008/0.009	0.010	0.010	0.003
18	-	0.017	0.013	0.010/0.009	0.011	0.012	0.003
19	-	0.016	0.010	0.009/0.010	0.012	0.011	0.003
20	-	0.076	0.035	0.010/0.016	0.293	0.086	0.026

TABLE A- 33

NITRITE
(mg N/l)

Station	8/4/75	8/5/75	8/6/75	8/7/75	8/8/75	Mean	Standard Deviation
3	0.11	0.013	0.034	0.021	0.012	0.038	0.041
4	0.003	0.003	0.031	0.012/0.009	0.006/0.006	0.010	0.010
5	0.020	0.009	0.029	0.019	0.009	0.017	0.008
6A	0.011	0.011	0.031	0.015	0.010	0.016	0.009
6B	0.011	0.008	-.035	0.013	0.007	0.015	0.012
7	0.073	0.097	0.086	0.033	0.073	0.072	0.024
7B	0.012	0.027	0.037	0.040	0.027	0.029	0.011
8	0.042	-	0.089/0.078	0.119	0.073	0.080	0.028
10	0.166	0.885	0.993	0.216	0.137	0.479	0.422
12	0.013	0.017	0.084	0.033	0.021	0.034	0.029
13	0.012	0.011	0.030	0.015	0.011	0.016	0.008
14	0.034	0.013	0.035	0.023	0.015	0.024	0.010
16	0.013	0.013	0.036	0.016	0.012	0.018	0.010
17	0.012	0.011	0.032	0.013	0.009	0.015	0.009
18	0.013	0.014	0.038	0.016	0.012	0.019	0.011
20	0.018	0.047	0.319	0.139	0.091	0.123	0.119

TABLE A- 34

NITRATE
(mg N/l)

Station	6/2/75	6/3/75	6/4/75	6/5/75	6/6/75	Mean	Standard Deviation
1	8.86/0.72	0.61	0.73	-	0.62	2.31	3.66
2	2.25/0.72	0.68	0.68	-	0.60	0.99	0.71
3	5.38/1.30	0.63	0.66	-	0.57	1.71	2.07
4	1.06/0.94	0.78	0.73	-	0.66	0.83	0.16
5	6.46	0.65	0.65	0.63	0.94	1.87	2.57
6	0.70	0.64	-	-	-	0.67	0.04
6A	-	-	0.66	0.53	0.994	0.73	0.24
6B	-	-	0.69	0.57	1.29	0.85	0.39
7	3.65	0.86	1.99	1.03	0.68	1.64	1.23
8	2.14	1.34	2.11	2.52	2.17	2.06	0.43
9	0.79	0.66	-	-	-	0.73	0.09
10	2.78	6.34	2.54	2.14	3.80	3.52	1.69
11	1.35	0.67	-	-	-	1.01	0.48
12	1.26	0.80/0.76	0.81	0.62	0.66	0.82	0.23
13	-	0.70	0.64/0.62	0.62	0.83	0.68	0.09
14	-	0.79	0.68/0.65	0.58	0.75	0.69	0.08
15	-	0.66	0.75	0.66/0.59	0.81	0.69	0.09
16	-	0.76	0.70	0.69/0.61	0.96	0.74	0.13
17	-	0.67	0.70	0.64/0.57	0.87	0.69	0.11
18	-	0.78	0.70	0.66/0.60	1.15	0.78	0.22
19	-	0.65	0.68	0.61/0.63	0.65	0.64	0.03
20	-	0.92	1.08	0.66/0.94	1.60	1.04	0.35

TABLE A- 35

NITRATE
(mg N/l)

Station	8/4/75	8/5/75	8/6/75	8/7/75	8/8/75	Mean	Standard Deviation
3	0.78	0.83	0.87	0.68	0.84	0.80	0.07
4	0.40	0.28	0.95	0.73/0.54	0.46/0.26	0.52	0.25
5	0.78	0.70	0.79	0.67	0.72	0.73	0.05
6A	0.86	0.99	0.63	0.77	0.78	0.81	0.13
6B	0.76	0.68	0.85	0.81	0.51	0.72	0.13
7	1.30	2.08	1.86	0.93	1.15	1.46	0.49
7B	1.04	0.92	0.92	0.81	0.73	0.88	0.12
8	2.72	-	2.77/2.07	8.20	2.02	3.56	2.62
10	1.93	12.0	14.2	9.1	7.67	8.98	4.69
12	0.93	1.06	1.33	1.32	0.96	1.12	0.19
13	0.89	0.92	0.67	0.80	0.70	0.80	0.11
14	1.00	0.74	0.78	0.80	0.65	0.79	0.13
16	0.93	0.79	0.81	0.80	0.57	0.78	0.13
17	0.80	0.68	0.72	0.72	0.57	0.70	0.08
18	0.77	0.73	0.86	0.83	0.56	0.75	0.12
20	0.95	2.01	4.14	4.55	3.73	3.08	1.53

TABLE A-36

TOTAL PHOSPHORUS
(mg P/l)

Station	6/2/76	6/3/76	6/4/76	6/5/76	6/6/76	Mean	Standard Deviation
1	0.045/0.041	0.086	0.043	-	0.039	0.051	0.020
2	0.081/0.093	0.111	0.074	-	0.080	0.088	0.015
3	0.082/0.044	0.280	0.095	-	0.063	0.114	0.066
4	0.025/0.032	0.044	0.037	-	0.037	0.035	0.007
5	0.096	0.319	0.176	0.271	0.081	0.189	0.105
6	0.074	0.089	-	-	-	0.082	0.011
6-A	-	-	0.170	0.204	0.155	0.176	0.025
6-B	-	-	0.064	0.083	0.094	0.080	0.333
7	0.070	0.132	0.075	0.086	0.052	0.083	0.030
8	0.061	0.073	0.041	0.129	0.039	0.069	0.035
9	0.087	0.181	-	-	-	0.134	0.066
10	0.121	0.227	0.138	0.130	0.158	0.155	0.043
11	0.079	0.206	-	-	-	0.143	0.090
12	0.082	0.093/0.101	0.073	0.094	0.113	0.093	0.014
13	-	0.175	0.147/0.094	0.131	0.185	0.146	0.036
14	-	0.080	0.058/0.066	0.081	0.079	0.073	0.010
15	-	0.160	0.144	0.176/0.099	0.162	0.148	0.030
16	-	0.075	0.386	0.074/0.090	0.077	0.140	0.137
17	-	0.098	0.102	0.104/0.096	0.089	0.098	0.006
18	-	0.069	0.067	0.088/0.079	0.073	0.075	0.009
19	-	0.235	0.128	0.176/0.221	0.123	0.177	0.052
20	-	0.096	0.063	0.080/0.109	0.081	0.086	0.017

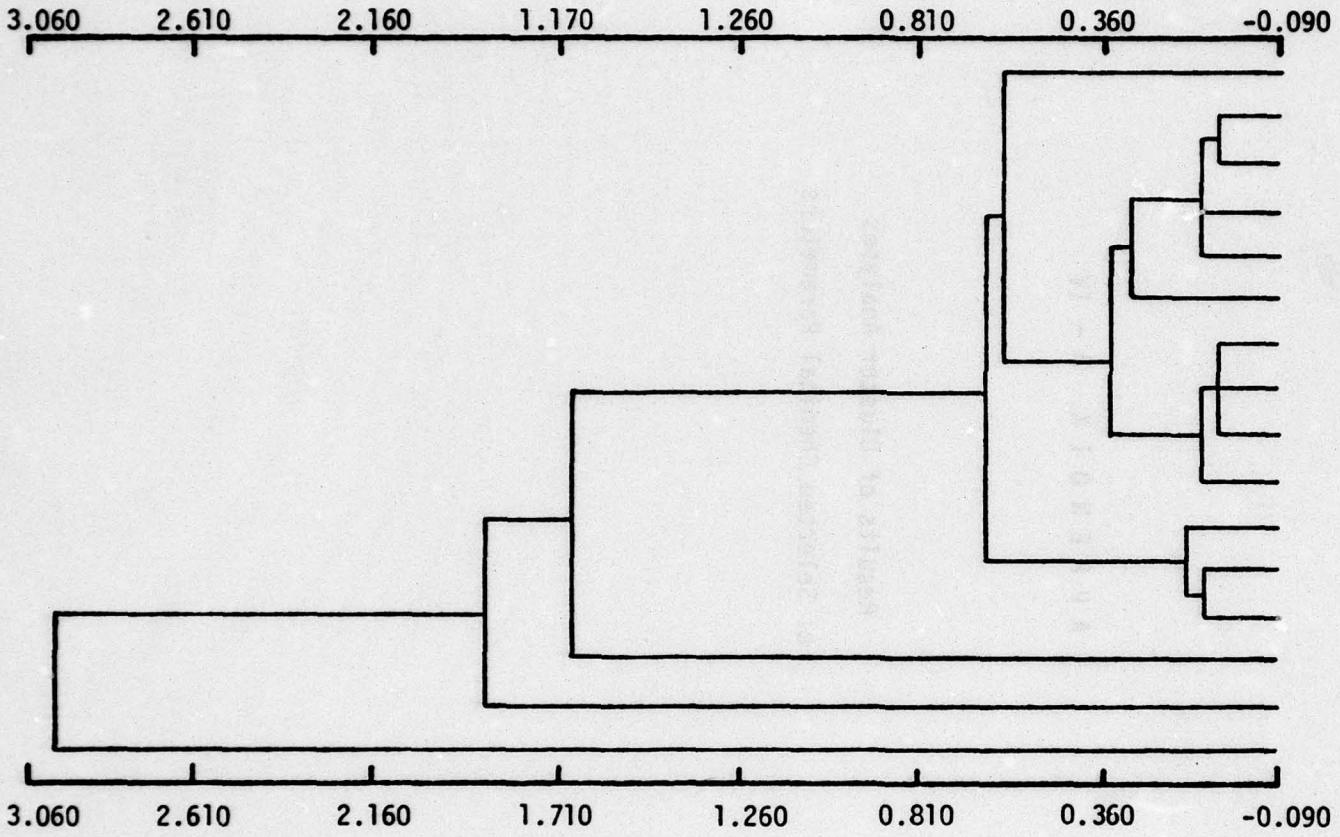
TABLE A-37

TOTAL PHOSPHORUS
(mg P/l)

Station	8/4/76	8/5/76	8/6/76	8/7/76	8/8/76	Mean	Standard Deviation
3	0.081	0.272	0.090	0.228	0.177	0.170	0.084
4	0.037	0.147	0.039	0.108/0.079	0.053/0.099	0.080	0.041
5	0.413	0.208	0.266	0.245	0.260	0.278	0.079
6-A	0.251	0.149	0.191	0.192	0.128	0.182	0.047
6-B	0.080	0.098	0.066	0.114	0.160	0.104	0.036
7	0.195	0.212	0.206	0.130	0.187	0.186	0.033
7-B	0.098	0.105	0.080	0.101	0.110	0.099	0.011
8	0.146	-	0.133/0.061	0.128	0.167	0.127	0.040
10	0.198	0.245	0.164	0.212	0.251	0.214	0.036
12	0.306	0.122	0.099	0.128	0.158	0.163	0.083
13	0.141	0.148	0.093	0.130	0.124	0.127	0.021
14	0.139	0.166	0.052	0.094	0.064	0.103	0.049
16	0.140	0.094	0.057	0.111	0.090	0.098	0.030
17	0.101	0.125	0.055	0.122	0.098	0.100	0.028
18	0.104	0.109	0.080	0.123	0.090	0.101	0.017
20	0.310	0.107	0.052	0.096	0.121	0.137	0.100

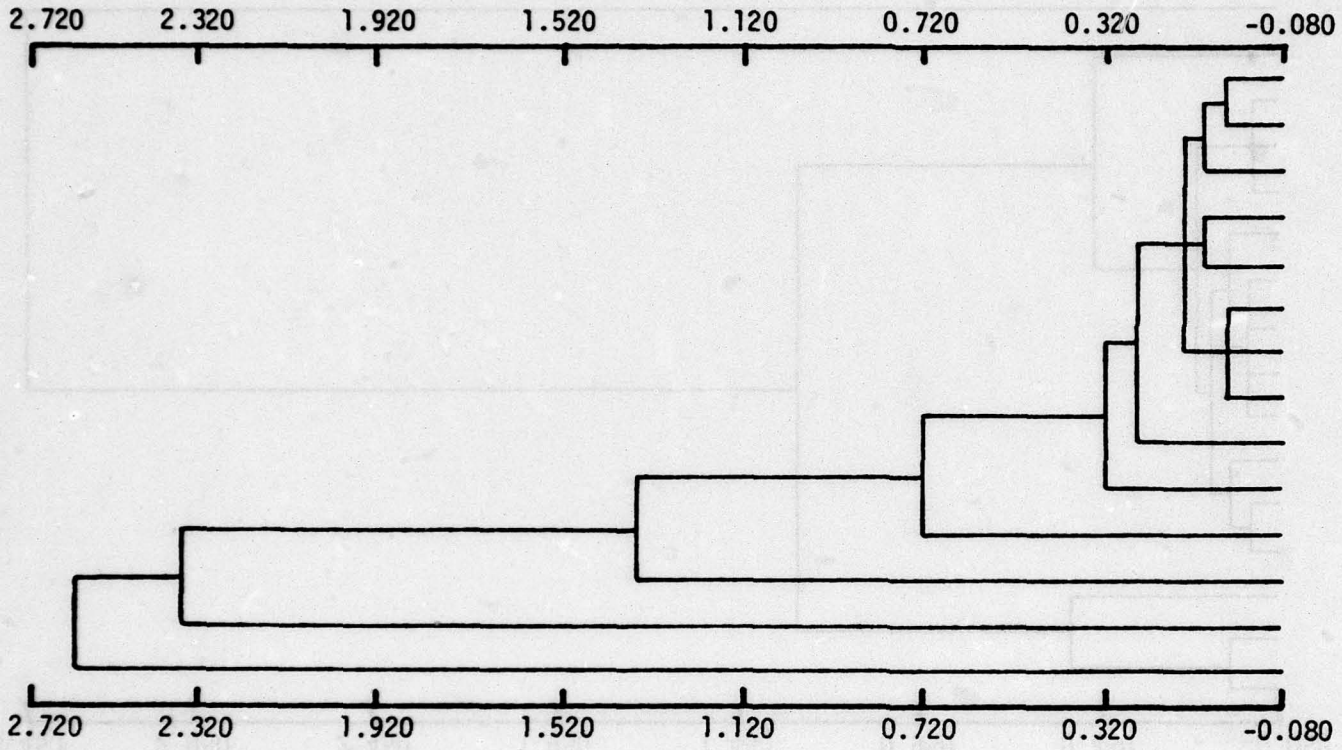
APPENDIX A - IV

Results of Cluster Analyses of Selected Chemical Parameters



Station	Level
3	0.5644
6-A	0.0490
14	0.0785
12	0.1004
16	0.2618
20	0.3020
4	0.0381
6-B	0.0538
18	0.1084
17	0.6290
13	0.1335
15	0.0777
19	1.6481
7	1.8978
10	2.9837
8	

FIGURE A-1. PHENOGRAM OF HOLSTON RIVER STATIONS AND HAAP EFFLUENTS (JUNE SURVEY) BASED ON TKN, NO_2 + NO_3 AND RDX. COPHENETIC CORRELATION COEFFICIENT, 0.983.



Station	Level
3	0.0519
17	0.0902
12	0.1060
4	0.0831
18	0.1363
6-A	0.0568
6-B	0.0431
13	0.2575
16	0.3184
14	0.7395
20	1.3697
7	2.3414
10	2.5861
8	

FIGURE A-2. PHENOGRAM OF HOLSTON RIVER STATIONS AND HAAP EFFLUENTS (AUGUST SURVEY) BASED ON TKN, NO_2 + NO_3 AND RDX-HMX. COPHENETIC CORRELATION COEFFICIENT, 0.992.

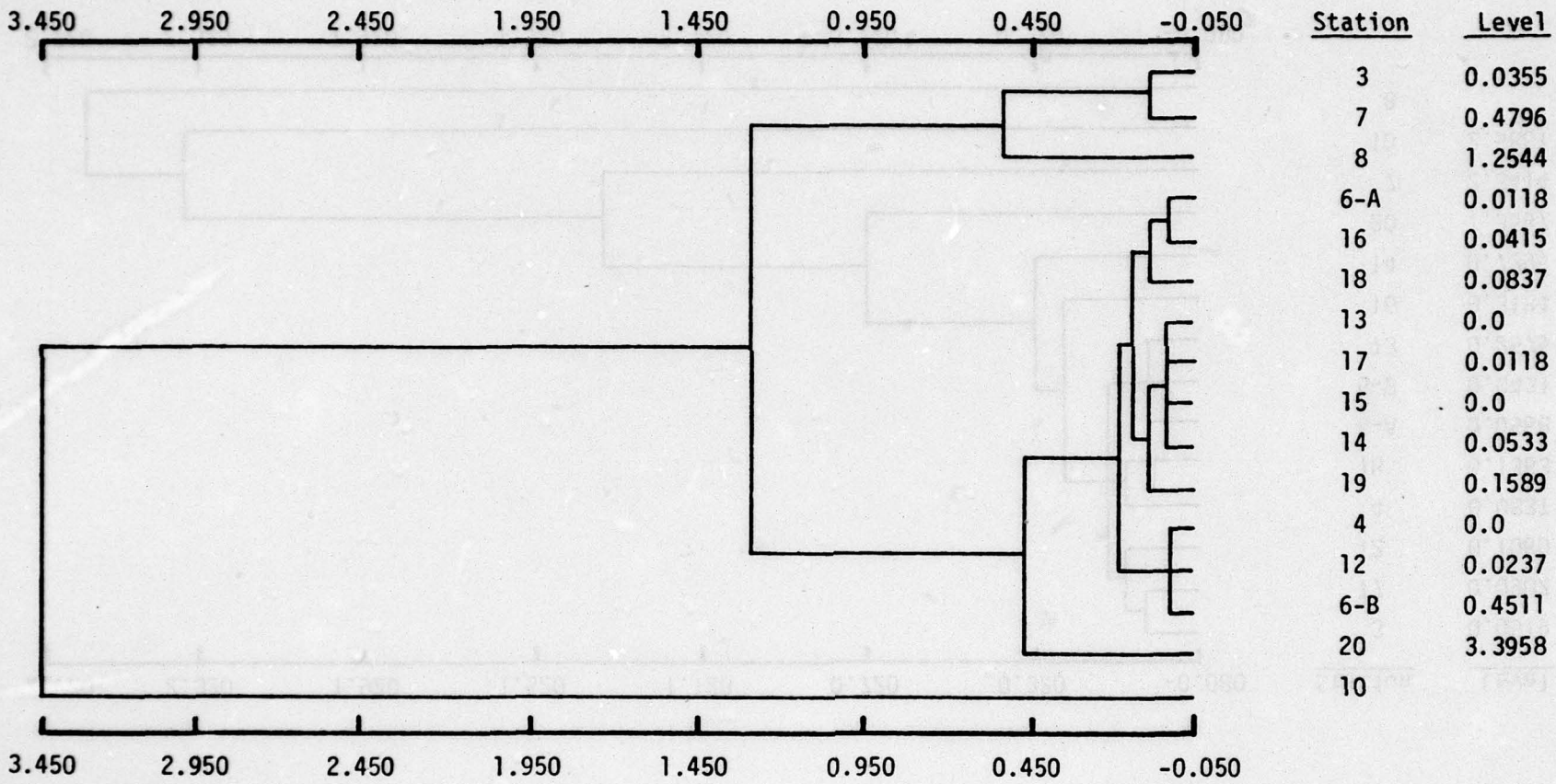


FIGURE A-3. PHENOGRAM OF HOLSTON RIVER STATIONS AND HAAP EFFLUENTS (JUNE SURVEY) BASED ON NO_2 + NO_3 ONLY. COPHENETIC CORRELATION COEFFICIENT, 0.975.

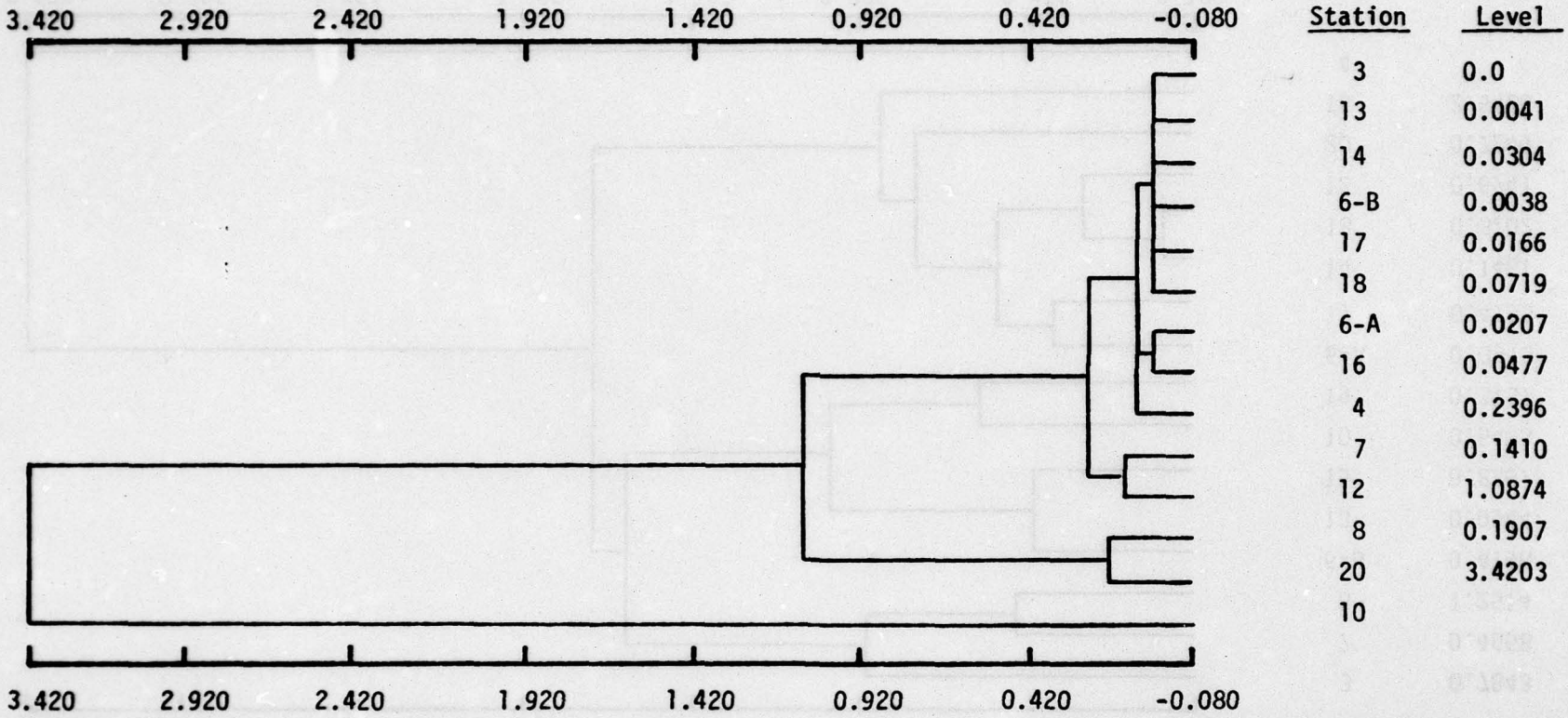
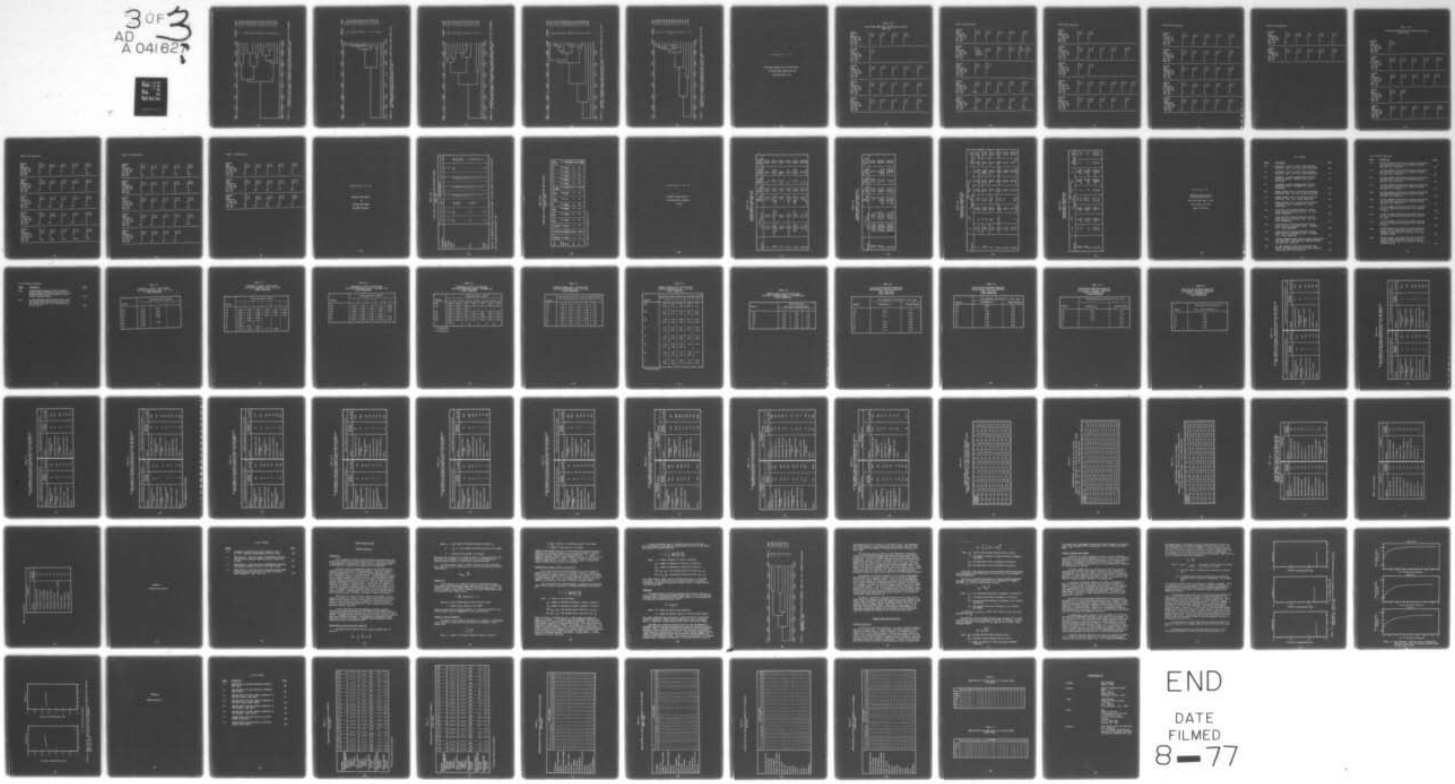


FIGURE A-4. PHENOGRAM OF HOLSTON RIVER STATIONS AND HAAP EFFLUENTS (AUGUST SURVEY) BASED ON $NO_2 + NO_3$ ONLY. COPHENETIC CORRELATION COEFFICIENT, 0.989.

AD-A041 627 WATER AND AIR RESEARCH INC GAINESVILLE FLA F/G 13/2
AQUATIC FIELD SURVEY AT HOLSTON ARMY AMMUNITION PLANT, KINGSPOR--ETC(U)
JUN 77 J H SULLIVAN, H D PUTNAM, M A KEIRN DAMD17-75-C-5049
UNCLASSIFIED NL

3 OF 3
AD A041627



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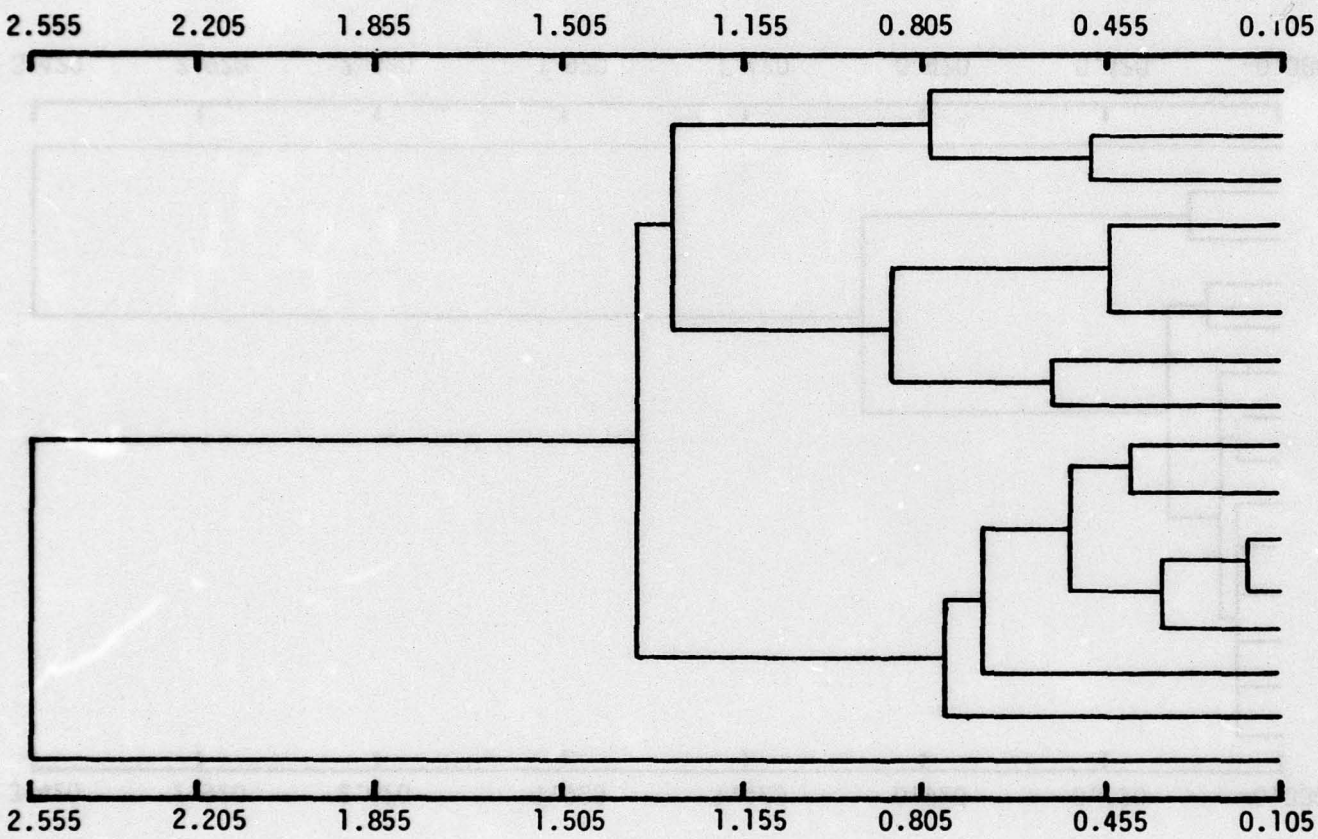
DATE FILMED
8-77



Station	Level
3	0.7843
7	0.4658
8	1.2514
6-B	0.4196
13	0.0944
15	0.8367
10	0.5403
19	0.3137
6-A	0.3913
17	0.4753
14	0.1461
18	0.3202
12	0.6741
20	0.7249
16	2.5426
4	

FIGURE A-5. PHENOGRAM OF HOLSTON RIVER STATIONS AND HAAP EFFLUENTS (JUNE SURVEY) BASED ON TOTAL PHOSPHORUS, Cl, SO_4, AND TOTAL HARDNESS. COPHENETIC CORRELATION COEFFICIENT, 0.902.

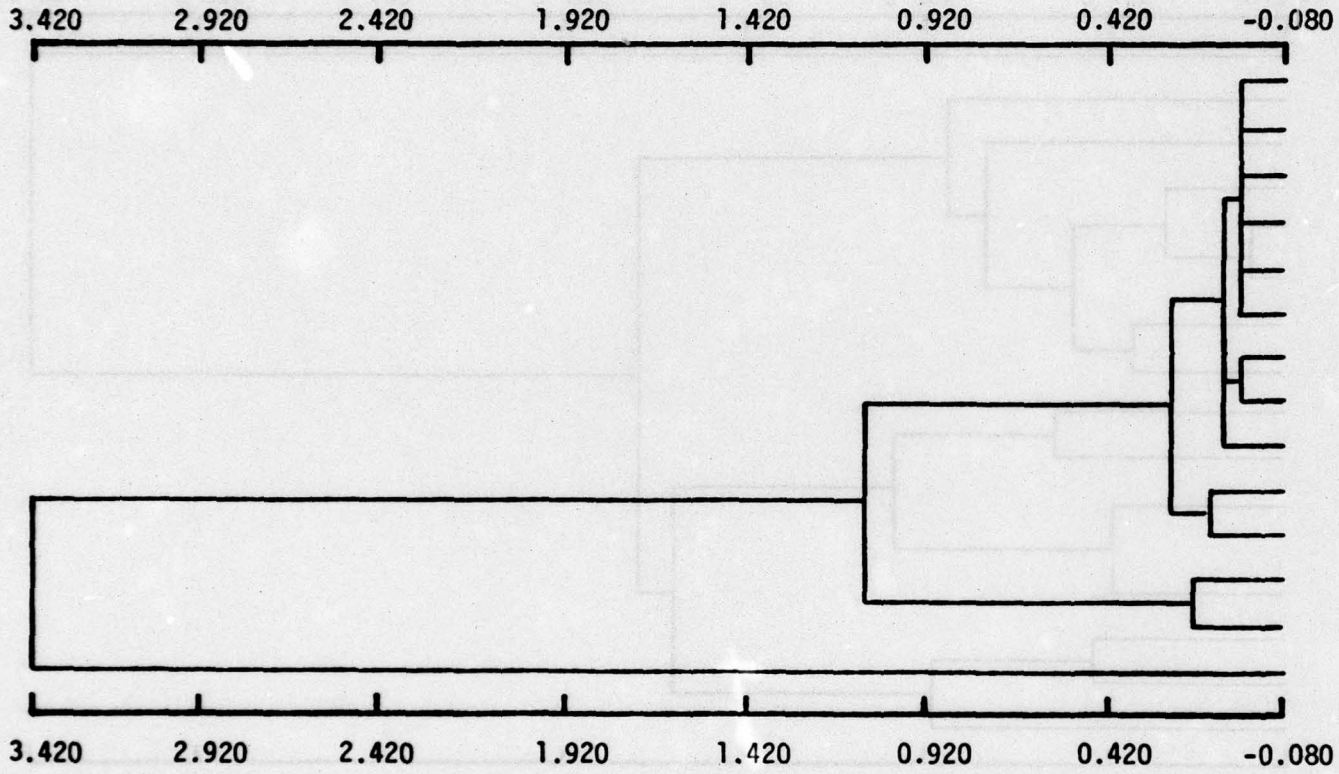


FIGURE A-4. PHENOGRAM OF HOLSTON RIVER STATIONS AND HAAP EFFLUENTS (AUGUST SURVEY) BASED ON NO_2 + NO_3 ONLY. COPHENETIC CORRELATION COEFFICIENT, 0.989.

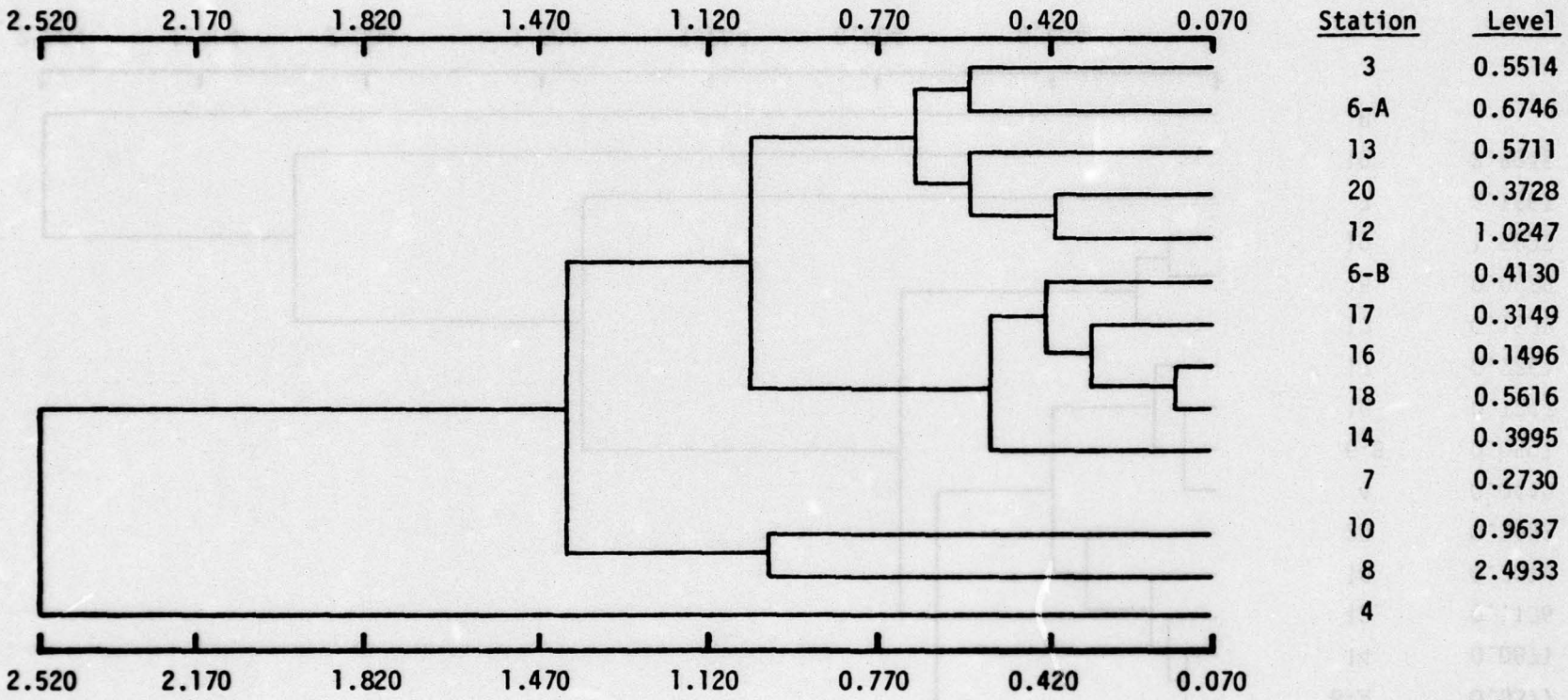


FIGURE A-6. PHENOGRAM OF HOLSTON RIVER STATIONS AND HAAP EFFLUENTS (AUGUST SURVEY) BASED ON TOTAL PHOSPHORUS, Cl, SO_4, AND TOTAL HARDNESS. COPHENETIC CORRELATION COEFFICIENT, 0.895.

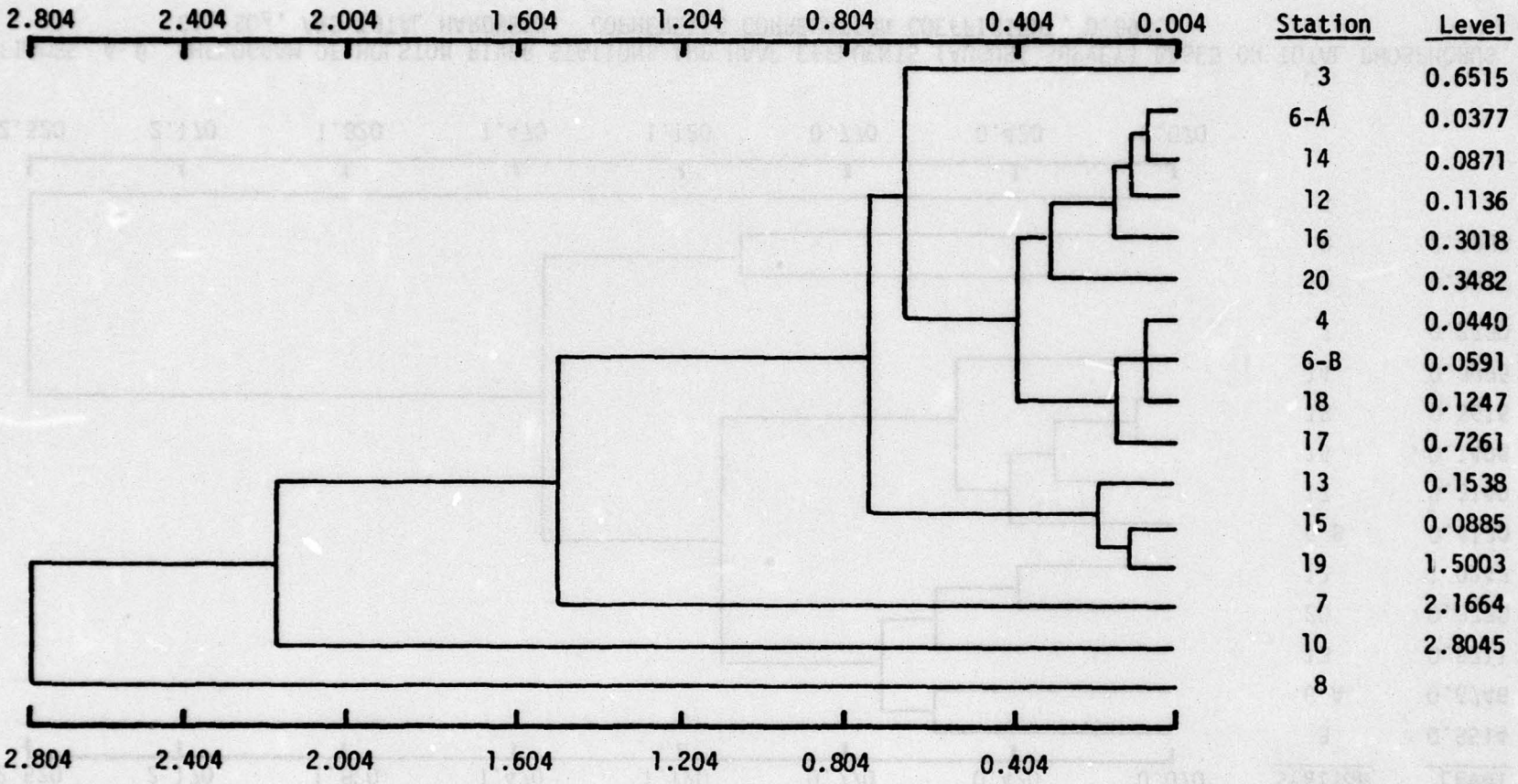


FIGURE A-7. PHENOGRAM OF HOLSTON RIVER STATIONS AND HAAP EFFLUENTS (JUNE SURVEY) BASED ON TKN, TOC, AND $NO_2 + NO_3$. COPHENETIC CORRELATION COEFFICIENT, 0.978.

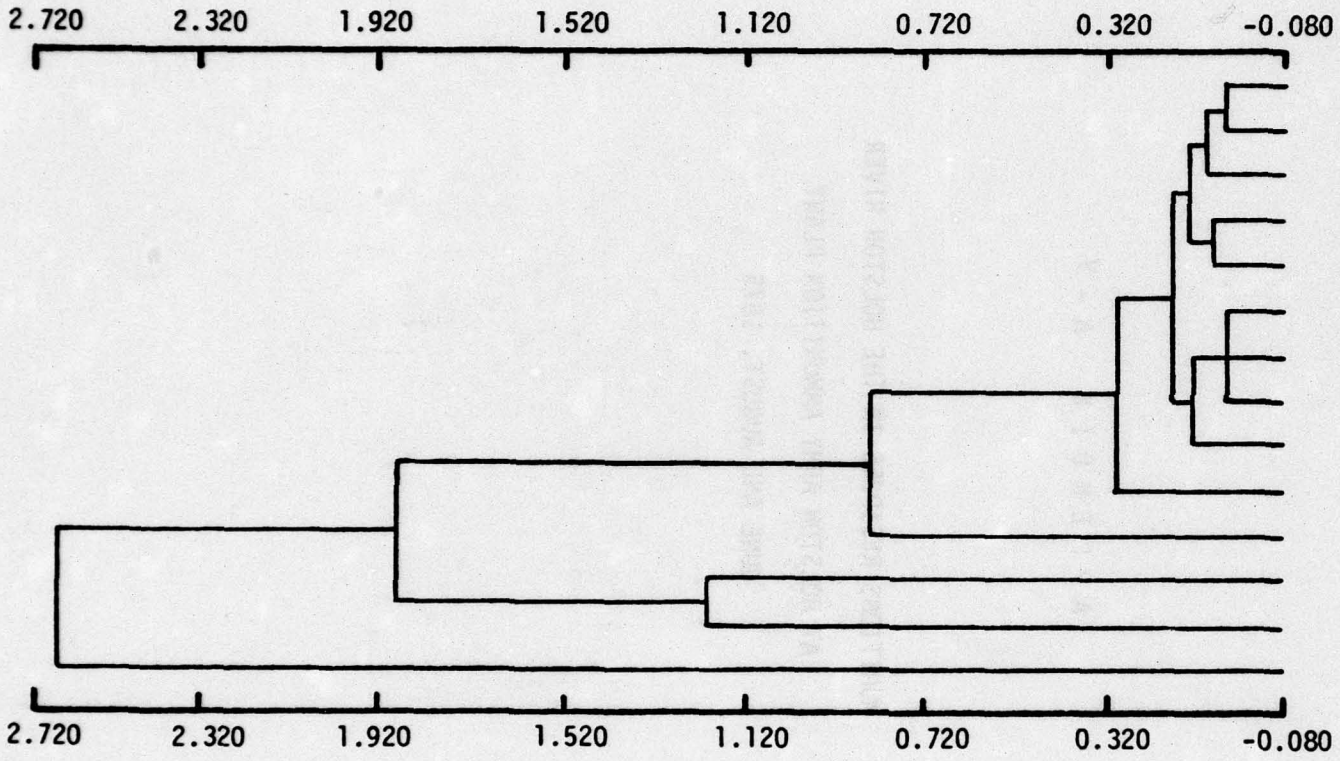


FIGURE A-8. PHENOGRAM OF HOLSTON RIVER STATIONS AND HAAP EFFLUENT (AUGUST SURVEY) BASED ON TKN, TOC, AND NO_2 + NO_3. COPHENETIC CORRELATION COEFFICIENT, 0.978.

APPENDIX A-V

MUNITIONS RESIDUES IN THE HOLSTON RIVER AT HOLSTON ARMY AMMUNITION PLANT JUNE AND AUGUST, 1975

TABLE A-38

HOLSTON ARMY AMMUNTIONS PLANT MUNITIONS RESIDUES
JUNE, 1975

STATION	1			
DATE	6-2-75	6-3-75	6-4-75	6-6-75
SAMPLE NO.	B-108	B-4	B-228	B-178
2,4 DNT, ppb	0	0	0	0
2,6 DNT, ppb	0	0	0	0
TNT, ppb	0	0	0	0
RDX, ppb	0	0	0	0

STATION	1
DATE	6-2-75
SAMPLE NO.	B-10
2,4 DNT, ppb	0
2,6 DNT, ppb	0
TNT, ppb	0
RDX, ppb	0

STATION	2				
DATE	6-2-75	6-2-75	6-3-75	6-4-75	6-6-75
SAMPLE NO.	B-100	B-2	B-9	B-224	B-175
2,4 DNT, ppb	0	0	0	0	0
2,6 DNT, ppb	0	0	0	0	0
TNT, ppb	0	0	0	0	0
RDX, ppb	0	0	0	0	0

STATION	3				
DATE	6-2-75	6-2-75	6-3-75	6-4-75	6-6-75
SAMPLE NO.	B-107	B-8	B-5	B-81	B-179
2,4 DNT, ppb	0	0	0	0	0
2,6 DNT, ppb	0	0	0	0	0
TNT, ppb	0	0	0	0	0
RDX, ppb	0	0	0	0	0

STATION	4				
DATE	6-2-75	6-2-75	6-3-75	6-4-75	6-6-75
SAMPLE NO.	B-104	B-6	B-1	B-78	B-147
2,4 DNT, ppb	0	0	0	0	0
2,6 DNT, ppb	0	0	0	0	0
TNT, ppb	0	0	0	0	0
RDX, ppb	0	0	0	<5	0

TABLE A-38 (Continued)

STATION	5				
DATE	6-2-75	6-3-75	6-4-75	6-5-75	6-6-75
SAMPLE NO.	B-106	B-12	B-82	B-151	B-18
2,4 DNT, ppb	0	0	0	0	0
2,6 DNT, ppb	0	0	0	0	0
TNT, ppb	0	0	0	0	0
RDX, ppb	0	0	0	0	0

STATION	6		6-A	6-B	6-A	6-B
DATE	6-2-75	6-3-75	6-4-75	6-4-75	6-5-75	6-5-75
SAMPLE NO.	Sample	B-142	B-74	B-217	B-70	B-68
2,4 DNT, ppb	broken in	0	0	0	0	0
2,6 DNT, ppb	shipment	0	0	0	0	0
TNT, ppb		0	0	0	0	0
RDX, ppb		0	0	0	0	0

STATION	6-A	6-B
DATE	6-6-75	6-6-75
SAMPLE NO.	B-20	B-16
2,4 DNT, ppb	0	0
2,6 DNT, ppb	0	0
TNT, ppb	0	0
RDX, ppb	0	0

STATION	7				
DATE	6-2-75	6-3-75	6-4-75	6-5-75	6-6-75
SAMPLE NO.	B-103	B-03	B-135	B-156	B-66
2,4 DNT, ppb	0	0	0	0	0
2,6 DNT, ppb	0	0	0	0	0
TNT, ppb	0	0	0	0	0
RDX, ppb	8200	248	832	46	775

STATION	8				
DATE	6-2-75	6-3-75	6-4-75	6-5-75	6-6-75
SAMPLE NO.	B-102	B-99	B-144	B-155	B-21
2,4 DNT, ppb	0	0	0	0	0
2,6 DNT, ppb	0	0	0	0	0
TNT, ppb	0	0	0	29	89
RDX, ppb	5040	0	8780	1500	1560

TABLE A-38 (Continued)

STATION	9	
DATE	6-2-75	6-3-75
SAMPLE NO.	B-101	B-138
2,4 DNT, ppb	0	0
2,6 DNT, ppb	0	0
TNT, ppb	0	0
RDX, ppb	0	0

STATION	10				
DATE	6-2-75	6-3-75	6-4-75	6-5-75	6-6-75
SAMPLE NO.	B-105	B-139	B-77	B-154	B-23
2,4 DNT, ppb	0	0	0	0	0
2,6 DNT, ppb	0	0	0	0	0
TNT, ppb	0	0	0	0	0
RDX, ppb	193	565	0	42	0

STATION	11	
DATE	6-2-75	6-3-75
SAMPLE NO.	B-97	B-137
2,4 DNT, ppb	0	0
2,6 DNT, ppb	0	0
TNT, ppb	0	0
RDX, ppb	0	743

STATION	12					
DATE	6-2-75	6-3-75	6-3-75	6-4-75	6-5-75	6-6-75
SAMPLE NO.	B-7	B-134	B-143	B-219	B-67	B-150
2,4 DNT, ppb	0	0	0	0	0	0
2,6 DNT, ppb	0	0	0	0	0	0
TNT, ppb	0	0	0	0	0	0
RDX, ppb	8	21	24	27	3	11

STATION	13				
DATE	6-3-75	6-4-75	6-4-75	6-5-75	6-6-75
SAMPLE NO.	B-76	B-227	B-221	B-71	B-17
2,4 DNT, ppb	0	0	0	0	0
2,6 DNT, ppb	0	0	0	0	0
TNT, ppb	0	<2	0	0	0
RDX, ppb	0	0	0	0	0

TABLE A-38 (Continued)

STATION	14				
DATE	6-3-75	6-4-75	6-4-75	6-5-75	6-6-75
SAMPLE NO.	B-79	B-84	B-222	B-72	B-19
2,4 DNT, ppb	0	0	0	0	0
2,6 DNT, ppb	0	0	0	0	0
TNT, ppb	0	0	0	0	0
RDX, ppb	48	104	150	33	29

STATION	15				
DATE	6-3-75	6-4-75	6-5-75	6-5-75	6-6-75
SAMPLE NO.	B-133	B-73	B-146	B-61	B-22
2,4 DNT, ppb	0	0	0	0	0
2,6 DNT, ppb	0	0	0	0	0
TNT, ppb	0	0	0	0	0
RDX, ppb	0	0	0	0	0

STATION	16				
DATE	6-3-75	6-4-75	6-5-75	6-5-75	6-6-75
SAMPLE NO.	B-80	B-83	B-149	B-69	B-15
2,4 DNT, ppb	0	0	0	0	0
2,6 DNT, ppb	0	0	0	0	0
TNT, ppb	0	0	0	0	0
RDX, ppb	0	0	0	0	0

STATION	17				
DATE	6-3-75	6-4-75	6-5-75	6-5-75	6-6-75
SAMPLE NO.	B-75	B-218	B-145	B-62	B-13
2,4 DNT, ppb	0	0	0	0	0
2,6 DNT, ppb	0	0	0	0	0
TNT, ppb	0	0	0	0	0
RDX, ppb	0	<5	<5	0	<5

STATION	18				
DATE	6-3-75	6-4-75	6-5-75	6-5-75	6-6-75
SAMPLE NO.	B-141	B-225	B-153	B-65	B-14
2,4 DNT, ppb	0	0	0	0	0
2,6 DNT, ppb	0	0	0	0	0
TNT, ppb	0	0	0	0	0
RDX, ppb	18	49	47	0	50

TABLE A-38 (Continued)

STATION	19				
DATE	6-3-75	6-4-75	6-5-75	6-5-75	6-6-75
SAMPLE NO.	B-136	B-220	B-64	B-148	B-24
2,4 DNT, ppb	0	0	0	0	0
2,6 DNT, ppb	0	0	0	0	0
TNT, ppb	0	0	0	0	0
RDX, ppb	100	0	5	5	5

STATION	20				
DATE	6-3-75	6-4-75	6-5-75	6-5-75	6-6-75
SAMPLE NO.	B-140	B-223	B-63	B-152	B-226
2,4 DNT, ppb	0	0	0	0	0
2,6 DNT, ppb	0	0	0	0	0
TNT, ppb	0	0	0	0	0
RDX, ppb	0	13	11	0	7

TABLE A- 39

HOLSTON ARMY AMMUNITIONS PLANT MUNITIONS RESIDUES
AUGUST, 1975

STATION	1-B
DATE	8-7-75
SAMPLE NO.	BA-172
2,4 DNT, ppb	0
2,6 DNT, ppb	0
TNT, ppb	0
RDX, ppb	0

STATION	3				
DATE	8-4-75	8-5-75	8-6-75	8-7-75	8-8-75
SAMPLE NO.	BA-209	BA-116	BA-119	BA-107	BA-131
2,4 DNT, ppb	0	0	0	0	0
2,6 DNT, ppb	0	0	0	0	0
TNT, ppb	0	0	0	0	0
RDX, ppb	0	0	0	0	0

STATION	4				
DATE	8-4-75	8-5-75	8-6-75	8-7-75	8-7-75
SAMPLE NO.	BA-207	BA-118	BA-120	BA-106	BA-106
2,4 DNT, ppb	0	0	0	0	0
2,6 DNT, ppb	0	0	0	0	0
TNT, ppb	0	0	0	0	0
RDX, ppb	0	0	0	0	0

STATION	4	
DATE	8-8-75	8-8-75
SAMPLE NO.	BA-177	BA-132
2,4 DNT, ppb	0	0
2,6 DNT, ppb	0	0
TNT, ppb	0	0
RDX, ppb	0	0

STATION	5				
DATE	8-4-75	8-5-75	8-6-75	8-7-75	8-8-75
SAMPLE NO.	BA-73	BA-114	BA-49	BA-178	BA-104
2,4 DNT, ppb	0	0	0	0	0
2,6 DNT, ppb	0	0	0	0	0
TNT, ppb	0	0	0	0	0
RDX, ppb	0	0	0	0	0

TABLE A-39 (Continued)

STATION	6-A				
DATE	8-4-75	8-5-75	8-6-75	8-7-75	8-8-75
SAMPLE NO.	BA-215	BA-211	BA-60	BA-100	BA-97
2,4 DNT, ppb	0	0	0	0	0
2,6 DNT, ppb	0	0	0	0	0
TNT, ppb	0	0	0	0	0
RDX, ppb	0	0	5	0	150

STATION	6-B				
DATE	8-4-75	8-5-75	8-6-75	8-7-75	8-8-75
SAMPLE NO.	BA-210	BA-214	BA-59	BA-108	BA-169
2,4 DNT, ppb	0	0	0	0	0
2,6 DNT, ppb	0	0	0	0	0
TNT, ppb	0	0	0	0	0
RDX, ppb	<5	0	0	0	<5

STATION	7				
DATE	8-4-75	8-5-75	8-6-75	8-7-75	8-8-75
SAMPLE NO.	BA-84	BA-117	BA-55	BA-176	BA-121
2,4 DNT, ppb	6	0	0	0	0
2,6 DNT, ppb	0	0	0	0	0
TNT, ppb	13	8	<2	0	0
RDX, ppb	320	900	440	280	<5

STATION	7-B				
DATE	8-4-75	8-5-75	8-6-75	8-7-75	8-8-75
SAMPLE NO.	BA-216	BA-208	BA-58	BA-99	BA-103
2,4 DNT, ppb	0	0	0	0	0
2,6 DNT, ppb	0	0	0	0	0
TNT, ppb	0	6	0	9	4
RDX, ppb	360	340	33	108	<5

STATION	8				
DATE	8-4-75	8-6-75	8-6-75	8-7-75	8-8-75
SAMPLE NO.	BA-80	BA-54	BA-57	BA-170	BA-128
2,4 DNT, ppb	0	<2	<2	0	0
2,6 DNT, ppb	0	<2	0	0	0
TNT, ppb	0	0	0	5	10
RDX, ppb	2220	2270	2190	2300	3780

TABLE A- 39 (Continued)

STATION	10				
DATE	8-4-75	8-5-75	8-6-75	8-7-75	8-8-75
SAMPLE NO.	BA-78	BA-110	BA-56	BA-180	BA-122
2,4 DNT, ppb	0	0	0	0	0
2,6 DNT, ppb	0	0	0	0	0
TNT, ppb	0	0	0	0	0
RDX, ppb	180	104	0	635	250

STATION	12				
DATE	8-4-75	8-5-75	8-6-75	8-7-75	8-8-75
SAMPLE NO.	BA-75	BA-212	BA-51	BA-102	BA-179
2,4 DNT, ppb	0	0	0	<2	0
2,6 DNT, ppb	0	0	0	0	0
TNT, ppb	0	0	0	0	0
RDX, ppb	0	73	42	59	70

STATION	13				
DATE	8-4-75	8-5-75	8-6-75	8-7-75	8-8-75
SAMPLE NO.	BA-81	BA-74	BA-52	BA-174	BA-123
2,4 DNT, ppb	0	0	0	0	0
2,6 DNT, ppb	0	0	0	0	0
TNT, ppb	0	0	0	0	0
RDX, ppb	5	0	22	0	40

STATION	14				
DATE	8-4-75	8-5-75	8-6-75	8-7-75	8-8-75
SAMPLE NO.	BA-82	BA-206	BA-53	BA-171	BA-126
2,4 DNT, ppb	<2	0	0	0	0
2,6 DNT, ppb	0	0	0	0	0
TNT, ppb	<2	0	0	0	0
RDX, ppb	210	525	0	125	700

STATION	16			
DATE	8-4-75	8-5-75	8-6-75	8-8-75
SAMPLE NO.	BA-76	BA-205	BA-112	BA-124
2,4 DNT, ppb	0	0	0	0
2,6 DNT, ppb	0	0	0	0
TNT, ppb	0	0	0	0
RDX, ppb	62	150	80	120

TABLE A- 39 (Continued)

STATION	17				
DATE	8-4-75	8-5-75	8-6-75	8-7-75	8-8-75
SAMPLE NO.	BA-83	BA-115	BA-113	BA-173	BA-127
2,4 DNT, ppb	0	0	0	0	0
2,6 DNT, ppb	0	0	0	0	0
TNT, ppb	0	0	0	0	0
RDX, ppb	<5	13	15	5	<5

STATION	18				
DATE	8-4-75	8-5-75	8-6-75	8-7-75	8-8-75
SAMPLE NO.	BA-79	BA-213	BA-111	BA-105	BA-125
2,4 DNT, ppb	0	0	0	0	0
2,6 DNT, ppb	0	0	0	0	0
TNT, ppb	0	0	0	0	0
RDX, ppb	0	105	100	93	104

STATION	20				
DATE	8-4-75	8-5-75	8-6-75	8-7-75	8-8-75
SAMPLE NO.	BA-77	BA-109	BA-50	BA-101	BA-98
2,4 DNT, ppb	0	0	0	0	0
2,6 DNT, ppb	0	0	<2	0	0
TNT, ppb	<2	0	<2	0	0
RDX, ppb	98	130	120	120	215

APPENDIX A - VI

Selected Trace Metals
in
Holston River Water
and HAAP Effluents

TABLE A-40A

TRACE METALS IN HOLSTON RIVER WATER AND HAAP EFFLUENTS
JUNE, 1975

Parameters*	Station Number**							
	3	4	6B	7	8	10	12	20
Cadmium	<5	<5	-	<5	<5	<5	<5	-
Chromium	<5	<5	-	<5	<5	<5	<5	-
Copper	15	<5	-	19	15	8	6	-
Iron	262	320	493	295	262	316	325	698
	-	-	334	285	169	308	-	375
	-	-	485	596	196	298	-	287
	-	-	-	275	236	233	-	405
	-	-	-	342	218	500	-	-
	-	-	-	320	116	204	-	-
Lead	<15	<15	<15	<15	<15	<15	-	<15
	-	-	<15	<15	<15	<15	-	<15
	-	-	<15	73	<15	<15	-	<15
	-	-	-	18	<15	<15	-	<15
	-	-	-	<15	<15	<15	-	<15
Nickel	5	<5	-	9	6	8	6	-
Zinc	<2	<2	-	6	<2	<2	<2	-

*Mercury - No detectable mercury 70.5 µg/l was found in 92 water samples from Stations 1 through 20.

**All concentrations expressed as µg/l.

TABLE A-40B

TRACE METALS IN HOLSTON RIVER WATER AND HAAP EFFLUENTS
AUGUST, 1975*

	3	4	5	6A	6B	7	7B	8	10	12	13	14	16	17	18	20
Mercury	<0.5 <0.5 <0.5 <0.5 <0.5	<0.5 <0.5 <0.5 <0.5 <0.5 <0.5	<0.5 <0.5 <0.5 <0.5 <0.5	0.5 <0.5	<0.5 <0.5	<0.5 <0.5		0.5 < 0.5 < 0.5	< 0.5 < 0.5 < 0.5	< 0.5 < 0.5 < 0.5 < 0.5 < 0.5						2.3* < 0.5 < 0.5
Chromium	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Copper	11	<5/<5 <5	<5 17	<5 7	<5 8	<5 9	<5 7	36	<5 10	<5 7	<5 6	<5 12	<5 8	<5 7	<5 7	<5 7
Iron	9 405	5/<5 185	14 316	8 267	5 177	10 203	9 339	184	9 239	5 126	9 163	<5 285	6 131	5 166	5 176	6 174
Lead	259 <15	574/512 <15	277 <15	214 <15	480 <15	219 <15	354 <15	<15	347 <15	224 <15	244 <15	364 <15	380 <15	251 <15	294 <15	256 <15
Nickel	<15 <5	<15/<15 6 20 42 <5	<15 <5	<15 <5	<15 <5	<15 <5	<15 <5	<5	<15 <5	<15 <2 10 2 <5	42 <5	<15 <5	<15 <5	<15 <5	<15 <5	<15 8/10 8/10 2/2 <5
Zinc	<5 91 45	<5/<5 <1 9 <1 41 31/37 51 77 10	<5 48 71	6 48 42	<5 18 43	<5 61 52	<5 38 66	66	<5 63 39	<5 <1 4 <1 61 38 12 66 37	<5 45 39	<5 78 25	<5 55 58	<5 27 21	<5 23 24	<5 4/6 2/<1 2/<1 37 39 54/55 32/29 24/14

*All concentrations expressed as µg/l.

A P P E N D I X A - VII

Chemical Characteristics of Holston River Sediments at HAAP

TABLE A-41

SEDIMENT CHEMICAL CHARACTERISTICS
HOLSTON RIVER AT HAAP, JUNE, 1975

Station	Solids % Total	Solids % Volatile	TKN (gm/Kg Dry Wt)	COD (gm/Kg Dry Wt)	NO_2-N (mg/Kg Dry Wt)	NO_3-N (mg/Kg Dry Wt)	Total P (mg/Kg Dry Wt)
1	54.3	3.3	0.75	15.4	<1	22	230
2	71.1	9.0	1.10	31.3	<1	28	590
3	52.3	0.8	1.58	25.5	1.4	21	480
4	76.0	0.8	0.55	3.1	1.0	25	210
6A	42.0/43.6/67.3	8.2/12.4/4.4	4.00/3.40	26.6	2.8	21/27	570
6B	66.0/59.0	2.5/6.3	0.36/1.30	63.9	1.7	21/29	330
7	73.9	2.8	.55	17.7	2.6	320	140
8	38.8	32.0	1.20	36.8	165	3200	360
9	49.9	8.1	1.70	16.9	2.0	64	510
10	70.0	2.1	.24	4.0	<1	13	170
12	53.5/59.9/61.6	6.4/6.8/7.4	1.50/1.60	23.0	<1	30/25	380
13	46.6	9.8	1.60	25.0	1.3	36	690
14	38.9/46.5	11.3/10.9	4.60/3.60	20.7	2.1	29/29	1500
15	54.6/59.1	4.8/8.1	0.90/1.50	44.4	1.2	65/28	260
16	38.6	8.7	2.70	18.0	1.7	47	720
17	62.1	4.3	.66	25.8	<1	40	500
18	49.1	10.4	3.00	35.9	<1	31	500
19	73.9	2.0	0.19	7.3	1.0	33	210
20	60.3/59.6	6.2/5.9	0.98/1.30	24.1	<1	65/36	580

TABLE A-42

SEDIMENT CHEMICAL CHARACTERISTICS
HOLSTON RIVER AT HAAP, AUGUST, 1975

Station	Solids % Total	Solids % Volatile	TKN (gm/Kg Dry Wt)	COD (gm/Kg Dry Wt)	NO_2-N (mg/Kg Dry Wt)	NO_3-N (mg/Kg Dry Wt)	Total P (mg Kg Dry Wt)
4B	67.0	3.3	1.10	40.0	0.78	42	330
6A	56.0/59.0	7.4/8.2	1.70	83.0	1.20	79	510
6B	60.0/58.0	6.1/6.6	1.30	43.0	0.94	47	410
7B	61.0/65.0	4.8/12.0	1.10	61.0	<0.91	36	450
8B	43.0/50.0	14.0/13.0	30.0	200.0	1.4	970	2200
12	42.0/52.0	12.0/11.0	29.0/26.0	220.0	1.7	2000/27	700
13	57.0/65.0	5.5/4.7	15.0/9.5	59.0	0.98	590/35	380
14	55.0/67.0	5.2/4.3	10.0/10.0	87.0	1.1	150/16	450
17	48.0/53.0	8.2/9.9	26.0	130.0	2.0	95/28	630
18	42.0/50.0	12.0/13.0	26.0/25.0	190.0	<1.3	11/46	810
20	22.0/27.0	23.0/14.0	62.0/29.0	360.0	<2.6	48/69	1100

TABLE A-43

SEDIMENT METAL CONCENTRATIONS
HOLSTON RIVER, JUNE, 1975

Station	Metal Concentration (mg/Kg Dry Wt)								
	Cd	Cr^{+6}	Cu	Hg	Ni	Pb	Zn	Fe (gm/Kg Dry Wt)	Mn
1	<2.2	-	28	-	13	63	240	16	0.42
2	<1.7	-	180	0.73	18	42	310	14	0.87
3	<2.6/4.0	47	79/94	0.40	32/28	120/150	360/360	20/23	0.86/0.93
4	<0.92/<1.6	33	2/4	<0.10	15/18	34/21	42/23	14/15	0.34/0.34
6A	<3.6	-	280	2.1	26	72	1000	25	1.20
6B	<2.6	26	41/56	0.62	19	52/19	110/210	21	0.49
7	<1.6/<0.95	22	40/45	<0.10	15/23	54/65	89/23	18/19	0.18/0.18
8	<3.1	26	58	4.1/0.31	15	93	201	12	0.28
9	<2.4	-	220	-	19	40	190	24	0.59
10	<1.7	-	8	<0.10/0.17	11/14	29	43	24	1.50
12	<0.19/<2.2	18/19/25	75/82/94	1.2	13/16	8/21/36	90/120/120	20/19	0.88/0.89
13	<2.6		1200	0.35	34	94	330	36	2.20
14	<3.1	-	110	2.6	25	120	770	28	1.80
15	<2.4		86		15	29	300	10	0.37
16	<3.0	-	57		30	76	420	25	1.20
17	<1.8	-	31	-	12	58	160	14	0.64
18	<2.4	-	31	-	19	36	170	18	0.80
19	<1.6	-	6	0.30	12	22	88	8.3	1.40
20	<2.0	35	110/250	0.76	49	12/76	210/260	.89	1.60

TABLE A-44

SEDIMENT METAL CONCENTRATIONS
HOLSTON RIVER, AUGUST, 1975

Station	Metal Concentration (mg/Kg Dry Wt)								
	Cd	Cr^{+6}	Cu	Hg	Ni	Pb	Zn	Fe (gm/Kg Dry Wt)	Mn
4B	<1.5	14	20	0.58	7	300	110	12	0.39
6A	-	50	650	-	-	26	210	-	-
6B	<2.3	25/42	16/81	0.58	15	26/450	93/280	17	0.56
7B	-	21	33	0.89	-	8	180	-	-
8B	-	110	220	5.10	-	38	810	-	-
12	<0.7	23/37	36/70	5.70	18	64/800	220/390	17	0.61
13	-	22	30	-	-	11	93	-	-
14	<0.5	23	42	0.95	15	510	270	14	0.34
17	<0.9	28/36	47/49	4.0	27	40/550	370/320	19	0.49
18	<0.7	37	74	6.3	19	820	360	20	0.42
20	<0.6	36	44	<0.10	22	990	260	31	2.50

A P P E N D I X B

Periphyton Data Collected
From the Holston River

USGS River Mile 139.8 - 136.5

June 11-July 10, 1975

August 12-26,1975

LIST OF TABLES

LIST OF TABLES (Continued)

LIST OF TABLES (Continued)

TABLE B-1

CHLOROPHYLL a LEVELS, HOLSTON RIVER
ARTIFICIAL SUBSTRATES, JUNE - JULY 1975
2-WEEK INCUBATIONS

Station	Replicate Results (gm/m^2)		
	1	2	3
4-B	0.013	0.021	-
6-A	0.028	0.051	-
6-B	0.032	0.023	-
17	0.016	0.030	-
18	0.034	-	-
20	0.035	0.008	-
12	0.027	-	-

TABLE B-2

CHLOROPHYLL a LEVELS, HOLSTON RIVER
ARTIFICIAL SUBSTRATES, JUNE - JULY 1975
4-WEEK INCUBATIONS

Station	Replicate Results (gm/m^2)					
	1	2	3	4	5	6
4-B	0.024	0.026	0.036	0.052	0.050	0.056
6-A	0.056	0.053	0.026	0.041	0.088	0.053
6-B	0.052	0.041	0.026	0.048	0.035	0.031
14	0.001	0.002	0.002	-	-	-
17	0.041	0.024	0.014	-	-	-
18	0.040	-	-	-	-	-
20	0.028	0.013	0.021	-	-	-
12	0.029	0.018	0.035	0.015	0.008	-

TABLE B-3

CHLOROPHYLL a LEVELS, HOLSTON RIVER
ARTIFICIAL SUBSTRATES, AUGUST - SEPTEMBER 1975
2-WEEK INCUBATIONS

Station	Replicate Results (gm/m^2)				
	1	2	3	4	5
4-B	0.019	0.013	0.012	0.011	0.026
6-B	0.035	0.023	0.016	0.024	0.024
7-B	0.046	0.037	0.037	0.037	0.028
8-B	0.014	0.020	0.014	0.019	-
13	<0.001	<0.001	<0.001	<0.001	<0.001
12	<0.001	<0.001	<0.001	<0.001	<0.001

TABLE B-4

CHLOROPHYLL a LEVELS, HOLSTON RIVER
ARTIFICIAL SUBSTRATES, AUGUST - SEPTEMBER 1975
4-WEEK INCUBATIONS

Station	Replicate Results (gm/m^2)						
	1	2	3	4	5	6	7
4-B	0.043	0.045	0.055	0.038	0.048	0.050	0.045
6-A*	0.004	0.006	0.005	0.001	0.001	0.001	0.004
	0.003	0.004	0.001				
6-B	0.047	0.034	0.039	0.043	0.041	0.052	0.034
7-B	0.039	0.033	0.027	0.024	0.008	0.018	0.103
8-B	0.007	0.018	0.014	0.031	0.009	0.018	0.031
12**	0.001	0.001	0.007	0.001	0.002	0.001	0.004
	0.003						

* 10 Replicates

** 8 Replicates

TABLE B-5

ORGANIC BIOMASS LEVELS, HOLSTON RIVER
ARTIFICIAL SUBSTRATES, JUNE - JULY 1975
2-WEEK INCUBATIONS

Station	Replicate Results (Ash Free Dry Weight) (gm/m^2)				
	1	2	3	4	5
4-B	5.49	9.23	2.77	4.21	5.17
6-A	1.92	2.19	3.04	3.73	3.25
6-B	2.45	4.00	4.37	4.00	1.81
14	4.48	7.57	4.27	4.96	7.52
17	0.85	2.67	2.13	3.73	2.29
18	12.30	11.50	11.60	15.00	7.73
20	6.61	6.40	5.71	5.97	6.35
12	2.67	3.25	6.93	4.05	2.45

TABLE B-6

ORGANIC BIOMASS LEVELS, HOLSTON RIVER
ARTIFICIAL SUBSTRATES, JUNE - JULY 1975
4-WEEK INCUBATIONS

Station	Replicate Results (Ash Free Dry Weight) (gm/m^2)				
	1*	2	3	4	5
4-B	3.87	5.32	6.35	3.46	4.13
	6.97	3.72	7.39	10.10	7.80
6-A	5.53	9.25	8.52	8.63	7.49
	9.25	7.81	7.08	5.81	10.40
6-B	4.55	1.45	4.60	8.37	7.65
	6.41	5.22	5.06	2.53	12.00
14	3.72	2.79	3.31	3.05	3.09
	6.87	6.51	6.72	4.33	5.06
17	1.66	2.43	1.50	1.91	2.43
	2.07	6.15	3.82	3.41	5.89
18	5.22	2.74	2.58	3.56	4.34
	4.14	6.56	6.53		
20	2.84	1.55	2.01	1.65	1.65
	1.14	2.11	2.12	2.94	
12	4.24	2.07	3.25	1.81	2.02
	3.52	3.46	5.17	3.82	4.49

* 8-10 Replicates

TABLE B-7

ORGANIC BIOMASS LEVELS, HOLSTON RIVER
ARTIFICIAL SUBSTRATES, AUGUST - SEPTEMBER 1975
2-WEEK INCUBATIONS

Station	Replicate Results (Ash Free Dry Weight)(gm/m^2)		
	1	2	3
4-B	1.83	2.56	1.61
6-B	1.53	2.93	3.94
7-B	4.93	2.10	6.77
8-B	1.78	0.48	1.34
13	2.05	3.20	3.15
12	3.15	2.98	3.47

TABLE B-8

CALCULATED NET PERIPHYTON PRODUCTION
HOLSTON RIVER, ARTIFICIAL SUBSTRATES
JUNE - JULY 1975
2-WEEK INCUBATIONS

Station	Net Production (gm C/m^2 day^{-1})- Calc. from:	
	Chlorophyll a	Organic Biomass
4-B	0.07	0.19
6A	0.17	0.10
6B	0.12	0.12
14	-	0.21
17	0.10	0.08
18	0.14	0.41
20	0.09	0.22
12	0.12	0.14

TABLE B-9

CALCULATED NET PERIPHYTON PRODUCTION
HOLSTON RIVER, ARTIFICIAL SUBSTRATES
JUNE - JULY 1975
4-WEEK INCUBATIONS

Station	Net Production (gm C/m^2 day^{-1}) - Calc. from:	
	Chlorophyll a	Organic Biomass
4-B	0.09	0.10
6-A	0.11	0.15
6-B	0.09	0.10
14	0.004	0.08
17	0.05	0.07
18	0.09	0.08
20	0.04	0.04
12	0.05	0.06

TABLE B-10

CALCULATED NET PERIPHYTON PRODUCTION
HOLSTON RIVER, ARTIFICIAL SUBSTRATES
AUGUST - SEPTEMBER 1975
2-WEEK INCUBATIONS

Station	Net Production (gm C/m^2 day^{-1})- Calc. from:	
	Chlorophyll *a*	Organic Biomass
4-B	0.07	0.07
6-B	0.10	0.10
7-B	0.16	0.17
8-B	0.07	0.04
13	-	0.14
12	-	0.11

TABLE B-11

CALCULATED NET PERIPHYTON PRODUCTION
HOLSTON RIVER, ARTIFICIAL SUBSTRATES
AUGUST - SEPTEMBER 1975
4-WEEK INCUBATIONS

Station	Net Production (gm C/m^2 day^{-1}) Calc. from Chlorophyll a
4	0.10
6-A	0.01
6-B	0.09
7-B	0.08
8-B	0.04
12	0.01

TABLE B-12

THE MOST ABUNDANT DIATOM SPECIES RECORDED FROM HOLSTON ARMY AMMUNITIONS PLANT ARTIFICIAL SUBSTRATES DURING JUNE-JULY 1975, STATION 4B

2-week Incubation Period, 6/11-6/23/75			4-week Incubation Period, 6/11-7/10/75		
Species	Percent Abundance	Cells/mm^2	Species	Percent Abundance	Cells/mm^2
Cocconeis placentula v. euglypta	43	2114	Achnanthes minutissima	41	6310
Gomphonema intricatum v. pumila	25	1247	Cocconeis placentula v. euglypta	36	5538
Achnanthes minutissima	17	818	Gomphonema intricatum v. pumila	13	2030
Rhoicosphenia curvata	5	230	Rhoicosphenia curvata	4	602
Cymbella sinuata	4	193	Cymbella sinuata	2	259
Others	6	292	Others	5	829

TABLE B-13

THE MOST ABUNDANT DIATOM SPECIES RECORDED FROM HOLSTON ARMY AMMUNITION PLANT ARTIFICIAL SUBSTRATES DURING JUNE-JULY 1975, STATION 6A

2-week Incubation Period, 6/11-6/23/75			4-week Incubation Period, 6/11-7/10/75		
Species	Percent Abundance	Cells/mm^2	Species	Percent Abundance	Cells/mm^2
Cocconeis placentula v. euglypta	37	1150	Cocconeis placentula v. euglypta	33	2421
Gomphonema angustatum v. producta	27	835	Gomphonema intricatum v. pumila	13	992
Gomphonema intricatum v. pumila	17	543	Gomphonema angustatum v. producta	12	900
Rhoicosphenia curvata	6	196	Rhoicosphenia curvata	12	900
Gomphonema parvulum	4	118	Achnanthes minutissima	8	625
Achnanthes minutissima	1.4	43	Nitzschia dissipata	7	549
Others	8	244	Others	13	982

TABLE B-14

THE MOST ABUNDANT DIATOM SPECIES RECORDED FROM HOLSTON ARMY AMMUNITION PLANT ARTIFICIAL SUBSTRATES DURING JUNE-JULY 1975, STATION 6B

2-week Incubation Period, 6/11-6/23/75			4-week Incubation Period, 6/11-7/10/75		
Species	Percent Abundance	Cells/mm^2	Species	Percent Abundance	Cells/mm^2
Cocconeis placentula v. euglypta	45	1678	Cocconeis placentula v. euglypta	33	3545
Gomphonema intricatum v. pumila	28	1038	Achnanthes minutissima	31	3353
Achnanthes minutissima	14	510	Gomphonema intricatum v. pumila	18	1966
Cymbella sinuata	6	241	Achnanthes lanceolata	7	761
Rhoicosphenia curvata	4	147	Rhoicosphenia curvata	2	249
Others	3	133	Others	8	872

TABLE B-15

THE MOST ABUNDANT DIATOM SPECIES RECORDED FROM HOLSTON ARMY AMMUNITION PLANT ARTIFICIAL SUBSTRATES DURING JUNE-JULY 1975, STATION 14

2-week Incubation Period, 6/11-6/23/75			4-week Incubation Period, 6/11-7/10/75		
Species	Percent Abundance	Cells/mm^2	Species	Percent Abundance	Cells/mm^2
Cocconeis placentula v. euglypta	56	541	Achnanthes minutissima	34	2283
Achnanthes minutissima	10	101	Cocconeis placentula v. euglypta	21	1412
Gomphonema intricatum v. pumila	7	66	Gomphonema intricatum v. pumila	9	580
Navicula cryptocephala v. intermedia	2	25	Stephanodiscus sp. 1*	5	319
Rhoicosphenia curvata	2	23	Achnanthes sp. A	4	281
Nitzschia dissipata	2	21	Gomphonema parvulum	3	213
Other	19	195	Rhoicosphenia curvata	2	143
			Others	22	1487

*Near Stephanodiscus invisitatus

TABLE B-16

THE MOST ABUNDANT DIATOM SPECIES RECORDED FROM HOLSTON ARMY AMMUNITION PLANT ARTIFICIAL SUBSTRATES DURING JUNE-JULY 1975, STATION 17

2-week Incubation Period, 6/11-6/23/75			4-week Incubation Period, 6/11-7/10/75		
Species	Percent Abundance	Cells/mm^2	Species	Percent Abundance	Cells/mm^2
Cocconeis placentula v. euglypta	34	2311	Achnanthes minutissima	44	9113
Gomphonema intricatum v. pumila	19	1252	Gomphonema intricatum v. pumila	15	3017
Achnanthes minutissima	18	1195	Cocconeis placentula v. euglypta	12	2569
Rhoicosphenia curvata	6	437	Rhoicosphenia curvata	3	691
Cymbella sinuata	4	250	Nitzschia kutzingiana	3	614
Gomphonema angustatum v. producta	3	223	Navicula minima	3	588
Others	16	1069	Others	20	4141

TABLE B-17

THE MOST ABUNDANT DIATOM SPECIES RECORDED FROM HOLSTON ARMY AMMUNITION PLANT ARTIFICIAL SUBSTRATES DURING JUNE-JULY 1975, STATION 18

2-week Incubation Period, 6/11-6/23/75			4-week Incubation Period, 6/11-7/10/75		
Species	Percent Abundance	Cells/mm^2	Species	Percent Abundance	Cells/mm^2
Cocconeis placentula v. euglypta	35	536	Achnanthes minutissima	36	2178
Gomphonema intricatum v. pumila	27	415	Gomphonema intricatum v. pumila	22	1369
Achnanthes minutissima	23	356	Cocconeis placentula v. euglypta	14	884
Rhoicosphenia curvata	3	49	Navicula cincta	3	176
Gomphonema parvulum	3	40	Rhoicosphenia curvata	2	140
Navicula cryptocephala v. veneta	2	29	Gomphonema parvulum	2	135
Others	7	129	Fragilaria vaucheriae	2	103
			Others	19	1149

TABLE B-18

THE MOST ABUNDANT DIATOM SPECIES RECORDED FROM HOLSTON ARMY AMMUNITION PLANT ARTIFICIAL SUBSTRATES DURING JUNE-JULY 1975, STATION 20

2-week Incubation Period, 6/11-6/23/75			4-week Incubation Period, 6/11-7/10/75		
Species	Percent Abundance	Cells/mm^2	Species	Percent Abundance	Cells/mm^2
Cocconeis placentula v. euglypta	45	310	Gomphonema intricatum v. pumila	41	1595
Gomphonema intricatum v. pumila	22	160	Cocconeis placentula v. euglypta	27	1045
Achnanthes minutissima	15	107	Achnanthes minutissima	21	808
Gomphonema parvulum	5	34	Gomphonema parvulum	3	128
Cymbella sinuata	4	27	Rhoicosphenia curvata	1	30
Rhoicosphenia curvata	1	9	Navicula minima	1	30
Others	8	52	Others	6	224

TABLE B-19

THE MOST ABUNDANT DIATOM SPECIES RECORDED FROM HOLSTON ARMY AMMUNITION PLANT ARTIFICIAL SUBSTRATES DURING JUNE-JULY 1975, STATION 12

2-week Incubation Period, 6/11-6/23/75			4-week Incubation Period, 6/11-7/10/75		
Species	Percent Abundance	Cells/mm^2	Species	Percent Abundance	Cells/mm^2
Cocconeis placentula v. euglypta	45	767	Gomphonema intricatum v. pumila	45	5881
Gomphonema intricatum v. pumila	24	415	Achnanthes minutissima	28	3643
Achnanthes minutissima	17	291	Cocconeis placentula v. euglypta	15	1885
Gomphonema parvulum	4	68	Rhoicosphenia curvata	3	343
Rhoicosphenia curvata	3	56	Cymbella sinuata	1	190
Cymbella sinuata	2	28	Gomphonema parvulum	1	181
Others	5	85	Others	6	806

TABLE B-20

THE MOST ABUNDANT DIATOM SPECIES RECORDED FROM HAAP ARTIFICIAL SUBSTRATES DURING AUGUST 1975, STATIONS 4B AND 6B

STATION 4B 2-Week Incubation Period			STATION 6B 2-Week Incubation Period		
Species	Percent Abundance	Cells/mm^2	Species	Percent Abundance	Cells/mm^2
Cocconeis placentula v. euglypta	48.3	3921	Gomphonema intricatum v. pumila	33.8	7970
Achnanthes sp. A	14.9	1215	Cocconeis placentula v. euglypta	23.9	5642
Gomphonema intricatum v. pumila	14.8	1203	Achnanthes minutissima	17.2	4059
Achnanthes minutissima	13.1	1066	Achnanthes sp. A	15.3	3612
Gomphonema parvulum	2.0	160	Gomphonema parvulum	4.6	1089
Others	6.9	559	Rhoicosphenia curvata	0.7	160
			Others	4.5	1034
Totals	100	8124	Totals	100	23566

TABLE B-21

THE MOST ABUNDANT DIATOM SPECIES RECORDED FROM HAAP ARTIFICIAL SUBSTRATES DURING AUGUST 1975, STATIONS 7B AND 8B

STATION 7B 2-Week Incubation Period			STATION 8B 2-Week Incubation Period		
Species	Percent Abundance	Cells/mm^2	Species	Percent Abundance	Cells/mm^2
Achnanthes sp. A	40.9	7612	Achnanthes sp. A	55.9	4840
Nitzschia kutzingiana	8.5	1581	Stephanodiscus sp. 1	5.6	481
Gomphonema intricatum v. pumila	4.8	894	Nitzschia kutzingiana	4.8	412
Gomphonema parvulum	4.8	893	Achnanthes minutissima	3.4	298
Stephanodiscus sp. 1	4.6	847	Gomphonema parvulum	3.2	274
Gomphonema angustatum v. producta	4.3	802	Gomphonema angustatum v. producta	2.7	240
Achnanthes minutissima	4.1	755	Gomphonema intricatum v. pumila	2.2	194
Fragilaria vaucherine	3.9	733	Fragilaria capucina	2.0	171
Others	24.1	4473	Cocconeis placentula v. euglypta	1.8	160
			Others	18.4	1591
Totals	100	18590	Totals	100	8661

TABLE B-22

THE MOST ABUNDANT DIATOM SPECIES RECORDED FROM HAAP ARTIFICIAL SUBSTRATES DURING AUGUST 1975, STATIONS 18 and 12

STATION 18 2-Week Incubation Period			STATION 12 2-Week Incubation Period		
Species	Percent Abundance	Cells/mm^2	Species	Percent Abundance	Cells/mm^2
Achnanthes sp. A	4.5	1238	Achnanthes minutissima	66.4	3153
Cocconeis placentula v. euglypta	21.6	596	Cocconeis placentula v. euglypta	19.5	928
Gomphonema intricatum v. pumlica	4.9	136	Achnanthes sp. A.	7.0	331
Stephanodiscus sp. 1	4.5	125	Cymbella affinis	1.4	68
Gomphonema parvulum	3.7	102	Gomphonema angustatum v. producta	1.2	56
Gomphonema angustatum v. producta	3.3	91	Gomphonema parvulum	0.7	34
Achnanthes minutissima	3.2	90	Others	3.8	176
Others	13.8	376			
Totals	100	2754	Totals	100	4746

TABLE B-23

PINKHAM-PEARSON (1974) INDICES OF BIOTIC SIMILARITY
(MUTUAL ABSENCE UNIMPORTANT) FOR HAAP ARTIFICIAL SUBSTRATE DIATOMS
DURING THE JUNE - JULY 1975 2-WEEK INCUBATION PERIOD

STATION / STATION	20	18	17	14	12	6B	6A	4B
4B	0.197	0.229	0.128	0.201	0.249	0.294	0.146	1.000
6A	0.124	0.181	0.110	0.164	0.181	0.187	1.000	******
6B	0.191	0.192	0.107	0.176	0.200	1.000	******	******
12	0.293	0.378	0.093	0.212	1.000	******	******	******
14	0.149	0.284	0.126	1.000	******	******	******	******
17	0.075	0.142	1.000	******	******	******	******	******
18	0.283	1.000	******	******	******	******	******	******
20	1.000	******	******	******	******	******	******	******

TABLE B-24

PINKHAM-PEARSON (1974) INDICES OF BIOTIC SIMILARITY
(MUTUAL ABSENCE UNIMPORTANT) FOR HAAP ARTIFICIAL SUBSTRATE DIATOMS
DURING THE JUNE - JULY 1975 - 4-WEEK INCUBATION PERIOD

STATION	20	19	17	14	12	08	0A	4B
4B	0.194	0.294	0.203	0.294	0.323	0.388	0.290	1.000
0A	0.222	0.300	0.200	0.300	0.257	0.273	1.000	------
08	0.197	0.339	0.220	0.283	0.275	1.000	------	------
12	0.209	0.299	0.186	0.278	1.000	------	------	------
14	0.114	0.332	0.240	1.000	------	------	------	------
17	0.088	0.236	1.000	------	------	------	------	------
19	0.140	1.000	------	------	------	------	------	------
20	1.000	------	------	------	------	------	------	------

TABLE B-25

PINKHAM-PEARSON INDICES OF BIOTIC SIMILARITY
(MUTUAL ABSENCE UNIMPORTANT) FOR HAAP ARTIFICIAL SUBSTRATE DIATOMS
COLLECTED DURING THE AUGUST 2-WEEK INCUBATION PERIOD

STATION / STATION	16	12	68	78	68	48	********	********
48	0.316	0.159	0.132	0.141	0.197	1.000	******	******
68	0.171	0.149	0.151	0.142	1.000	******	******	******
78	0.076	0.044	0.258	1.000	******	******	******	******
88	0.166	0.086	1.000	******	******	******	******	******
12	0.216	1.000	******	******	******	******	******	******
16	1.000	******	******	******	******	******	******	******

TABLE B-26

THE MOST ABUNDANT DIATOM SPECIES RECORDED FROM HAAP NATURAL PERIPHYTON SUBSTRATES (BLUE-GREEN ALGAL MAT) DURING JUNE 1975, STATIONS 4B, 6B, 14, 18, and 12

STATION 4B		STATION 6B	
Species	Percent Abundance	Species	Percent Abundance
Navicula sp. 1	9.7	Achnanthes minutissima	9.8
Achnanthes minutissima	8.7	Cymbella ventricosa	6.5
Navicula cryptocephala	7.9	Achnanthes affinis	5.8
Fragilaria pinnata	5.6	Navicula sp. 1	5.0
Nitzschia kutzingiana	4.8	Amphora sp. 1	4.2
Rhoicosphenia curvata	3.6	Melosira varians	3.3
Amphora sp. 1	3.4	Navicula minima	3.1
Cyclotella stelligera	3.2	Navicula cryptocephala	3.1
Cymbella ventricosa	3.0	Cocconeis placentula v. euglypta	2.9
Nitzschia palea	3.0	Rhoicosphenia curvata	2.9

TABLE B-26 (Continued)

STATION 14		STATION 18	
Species	Percent Abundance	Species	Percent Abundance
Nitzschia parvula	10.2	Nitzschia kutzingiana	10.0
Nitzschia kutzingiana	9.4	Achnanthes affinis	6.7
Achnanthes minutissima	5.5	Gyrosigma sp.	5.4
Rhoicosphenia curvata	4.9	Navicula minimo	5.2
Navicula luzonensis	4.7	Amphora ef. perpussilla	4.6
Navicula minima	4.7	Fragilaria capucina	4.6
Diatoma vulgare	3.9	Achnanthes minutissima	4.2
Navicula sp. 1	3.9	Navicula sp. 3	3.8
Melosira varians	3.9	Navicula sp. 2	3.6
Amphora sp. 1	3.7		

TABLE B-26 (Continued)

STATION 12	
Species	Percent Abundance
Achnanthes minutissima	10.4
Nitzschia kutzingiana	8.0
Navicula cryptocephala	6.4
Cymbella microcephala	5.8
Cyclotella stelligera	4.6
Achnanthes affinis	4.0
Cocconeis placentula v. euglypta	4.0
Navicula minima	4.0
Cymbella ventricosa	3.4
Cocconeis pediculus	3.2

APPENDIX C

Computational Methods

LIST OF FIGURES

COMPUTATIONAL METHODS

Community Analysis

Introduction

Biotic components of water quality are generally quantified by one-dimensional diversity indices when single samples or stations are examined, or two-dimensional coefficients of biotic similarity when sample/sample, station/station, or species/species comparisons are undertaken.

Diversity indices are mathematical expressions that describe the distribution of individuals within the community. There are a number of diversity expressions in use. In general, maximum diversity exists if each individual belongs to a different species. Minimum diversity exists if all individuals belong to the same species. An environmental parameter that influences community structure will also modify the diversity index. In cases where environmental stress may occur (such as competition among species, physiochemical limiting factors, or pollution), the community is reduced in the number of species present. Frequently, this reduction in the number of species is accompanied by an increase in the number of individuals of the remaining species, especially in the case of organic pollution. Environmental stress, therefore, tends to reduce the magnitude of diversity indices. One-dimensional diversity indices include the Shannon-Weaver Species Diversity, Evenness, and Simpson's Index of Dominance.

Coefficients of biotic similarity quantify the taxonomic overlap between two samples or stations. Most of these coefficients assume values between 0 and 1, where a value of 0 indicates no species overlap, and a value of 1 implies identical species composition. Morisita's Index of Faunal Affinity and the Pinkham-Pearson's Index of Biotic Similarity are measures of biotic similarity.

In this study data processing subsequent to manual taxonomic identification/confirmation was executed through the IBM 370/OS system at the Northeast Regional Data Center of the State University System of Florida (NERDC). Diversity indices and coefficients of similarity were calculated by proprietary FORTRAN IV routines. The phenograms were generated through application of the NT-SYS Numerical Taxonomy System developed by Rohlf, Kishpaugh and Kirk at Stony Brook (1974).

Shannon-Weaver Species Diversity Index ($\bar{H}$)

The Shannon Weaver Species Diversity Index, $\bar{H}_e$ (Odum, 1971) is defined as:

$$\bar{H}_e \equiv \sum_{i=1}^{t} - \frac{n_i}{N} \ln \frac{n_i}{N}$$

where n_i = total number of organisms persent as species $\underline{i}$

$N = \sum_{i=1}^{t} n_i$ = total number of organisms present in the sample

t = number of taxa present in the sample

$\bar{H}e$ ranges from a minimum of 0.0, occurring when all organisms belong to the same taxon (no diversity), to a maximum of ln N, occurring where each organism present belongs to a unique taxon (maximum diversity).

The Shannon-Weaver Index is commonly expressed to other logarithmic bases, especially base 2 and base 10, and is easily converted by the following expression:

$$\bar{H}_{base_X} = \frac{\bar{H}_e}{\ln_X}$$

Evenness (e)

If the organisms of a sample are uniformly distributed among the taxa present, the Shannon-Weaver Index assumes the value, ln t, a condition of perfect evenness in the apportionment of individuals among species. The Index of Evenness, e (Odum, 1971), expresses the actual Shannon-Weaver Index as a fraction of this "ideal" value:

$$e \equiv \frac{\bar{H}_e}{\ln t} \quad \text{(defined for } t > 1\text{)}$$

where $\bar{H}_e$ = actual Shannon-Weaver Species Diversity Index

t = number of taxa present in the sample

Evenness ranges from 0.0 (minimum evenness) to 1.0 (perfect evenness), and the calculated values are independent of the logarithmic base.

Simpson's Index of Dominance

The degree to which numerical dominance of a community is concentrated in one, several, or many species may be quantified by Simpson's Index, c (Odum, 1971):

$$c \equiv \sum_{i=1}^{t} \left(\frac{n_i}{N}\right)^2$$

where n_i = number of individual organisms present as species $\underline{i}$

$N = \sum_{i=1}^{t} n_i$ = total no. of organisms present in the sample.

t = number of taxa present in the sample

Simpson's Index ranges from 1/N, occurring when each organism represents a unique species (minimum dominance), to 1.0, occurring when all organisms represent the same single species (maximum dominance). In an evenly-dominated community, Simpson's Index assumes the value, 1/t, where t is the number of taxa observed in a sample -- $\overline{H}$ and e, for such a case, assume respective magnitudes of ln t and 1.0. Simpson's Index is therefore inversely related to species diversity and evenness.

Pinkham-Pearson Index of Biotic Similarity (B)

Each of the previously discussed indices ($\overline{H}$, e, and c) quantify community structure with a sacrifice of taxonomic integrity important to paired comparisons between samples or stations. Such indices are incapable of distinguishing samples of similar gross community structure, but unlike taxonomic composition. That is, in computation, the i th species of one sample is not necessarily the same i th species of another sample.

This insensitivity to taxonomic overlap is surmounted by the Pinkham Pearson Index of Biotic Similarity, B (Pinkham and Pearson, 1974) defined as:

$$B \equiv \frac{1}{t} \sum_{i=1}^{t} \frac{\text{Min } (n_{iA}, n_{iB})}{\text{Max } (n_{iA}, n_{iB})}$$

where t = number of taxa considered

n_{iA} = number of organisms of species i present at Station A

n_{iB} = number of organisms of species i present at Station B

Min (n_{iA}, n_{iB}) = the minimum value of the pair: n_{iA}, n_{iB}

Max (N_{iA}, n_{iB}) = the maximum value of the pair: n_{iA}, n_{iB}

Biotic similarity is defined only for a paired comparison between two samples or stations. If two samples are characterized by identical taxonomic overlap (all species occur in identical abundance), the calculated index assumes a value of 1.0 (maximum similarity). Two samples possessing no species in common share an index of 0.0 (minimum or no similarity). The number of species considered, t, may include only those species observed in either or both of the two samples, or, if mutual absence is deemed important, may include species not necessarily present in either sample. If mutual absence is considered important, Min (0,0) ≡ 1 and Max (0,0) ≡ 1 in the computation of biotic similarity.

A biotic similarity index, B', between species may be defined on spatial and numerical occurrence by transposition of the axes in the preceding expression of station similarity:

$$B' \equiv \frac{1}{k} \sum_{j=1}^{k} \frac{\text{Min } (n_{j1}, n_{j2})}{\text{Max } (n_{j1}, n_{j2})}$$

where: k = number of samples or stations considered

n_{j1} = number of organisms of species 1 at Station j

n_{j2} = number of organisms of species 2 at Station j

Min (n_{j1}, n_{j2}) = the minimum value of the pair: n_{j1}, n_{j2}

Max (n_{j1}, n_{j2}) = the maximum value of the pair: n_{j1}, n_{j2}

This index likewise ranges from 0.0 (minimum similarity) to 1.0 (maximum similarity). B' may possess utility for grouping species according to environmental preference or pollution tolerance--that is, it may delineate "indicator organisms."

Phenograms

The quantification of similarity between paired stations, samples, or species by any of the previously-defined coefficients of similarity generates a diagonal matrix containing PC unique elements, where PC is calculated from the expression (Pinkham and Pearson, 1974):

$$PC = \frac{S\,(S - 1)}{2}$$

where: PC = number of unique paired comparisons

S = number of stations, samples, or species being compared

For a study comprising only 25 stations, a similarity matrix of 300 unique elements is produced. Evaluation and presentation of such a voluminous matrix is impractical without computer-aided analysis and graphic models.

Algorithms for clustering similarity matrices into two-dimensional, hierarchic relationships have been developed by numerical taxonomists (Sokal and Sneath, 1963). A technique frequently invoked by ecologists and generally regarded as introducing the least distortion into similarity relationships is the sequential, agglomerative, hierarchic, nonoverlapping clustering method (SAHN) using unweighted pair-groups with arithmetic averaging (UPGMA), described by Sokal and Sneath (1963). The product of this procedure is a branched diagram termed a phenogram (or dendrogram), illustrated below for a study of

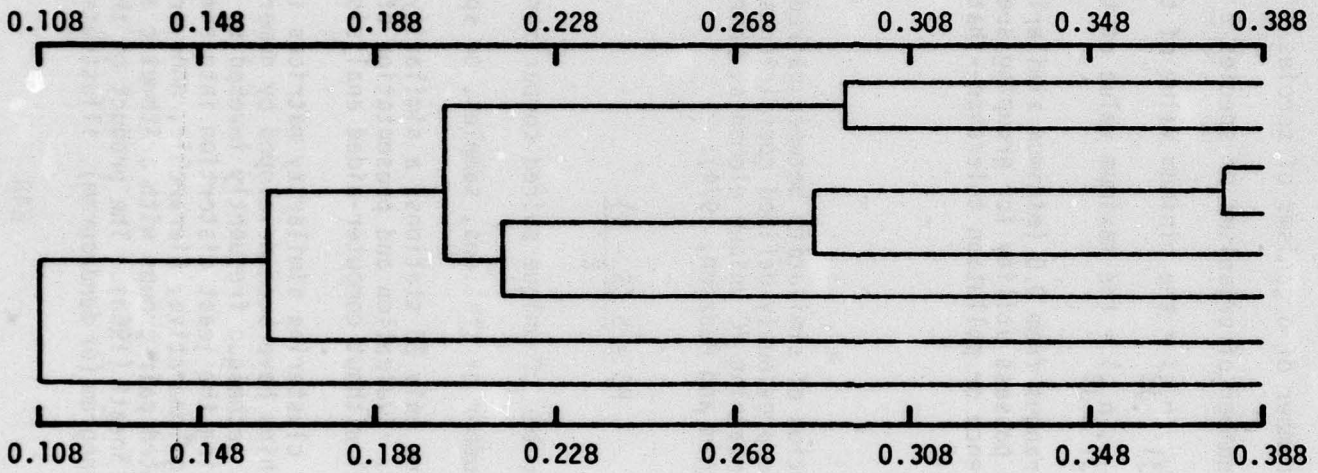


FIGURE C-1. PHENOGRAM OF PERIPHYTON ARTIFICIAL SUBSTRATE, JUNE 11-26, 1975. COPHENETIC CORRELATION COEFFICIENT, 0.927.

diatom populations at six stations in the Holston River. This phenogram, like those contained in the current study, was generated directly by computer using the NT-SYS Numerical Taxonomy Package (Rohlf, Kishpaugh, and Kirk, 1974).

The horizontal scale or abscissa of the phenogram is graduated in the units of the similarity measure upon which the clustering was based -- in this case, the Pearson-Pinkham Biotic Similarity Index (mutual absence unimportant). Points of furcation (branching) between the horizontal stems, representing stations or groups of stations imply that the similarity between the two streams is at the coefficient value shown above the branch on the abscissa. The magnitude of similarity between stems is also shown to the right of the phenogram under the column heading, "Level;" these numbers give the exact similarity level at which each stem (station or group of stations) joins the stem below it. Stems are associated with their respective stations by labels to the right under the column heading "Station."

The magnitude of similarity between any two stations represented on the phenogram will, in general, differ from the corresponding magnitude given in the original similarity matrix. This arises as a consequence of the averaging necessary to recursively agglomerate the separate stations into a single, structured set containing all the stations. In the illustrative phenogram, the level of similarity between Stations 6B and 14 is shown to be 0.2044, whereas, in the original similarity matrix (not shown), the magnitude is given as 0.1720. The phenogram value is the arithmetic average of the original similarity indices of Stations 4B and 6B (the cluster containing Station 6B) respectively paired with Stations 12, 18, 20, and 14 (the cluster containing Station 14).

The degree of distortion resulting from the cluster analysis may be quantified by the cophenetic correlation coefficient, r_{coph}, defined as the product moment correlation coefficient computed between the elements of the original similarity matrix and the corresponding indices implied by the phenogram (Sokal and Sneath, 1963). High values of r_{coph} ($r_{coph} > 0.8$ for fewer than 10 stations) indicate that the distortion introduced by the clustering procedure and depicted by the phenogram has not significantly masked the informational content of the original similarity matrix.

Chemical Water Quality Analysis

Distance Coefficient

The prior discussion has focused upon the numerical measures generally applied to biologic data. A somewhat more generalized approach to paired comparisons between stations, readily extended to the interpretation of chemical data, is the distance measure. The procedure treats stations as points in an n-dimensional hyperspace, where the n coordinates of a station are the values of the n chemical or chemical/biologic parameters considered. Analogous to the biotic similarity coefficients, a matrix of Euclidean distance coefficients is calculated from the expression (Sokal and Sneath, 1963):

$$\Delta_{AB} \equiv \left[\sum_{i=1}^{n} (X_{iA} - X_{iB})^2 \right]^{\frac{1}{2}}$$

where Δ_{AB} = the Euclidean distance between Stations A and B

n = the number of chemical or chemical/biologic parameters considered

X_{iA} = the magnitude of the $\underline{i}$ th parameter at Station A

X_{iB} = the magnitude of the $\underline{i}$ th parameter at Station B

Clustering is then executed by grouping together station pairs possessing low distance coefficients, that is, stations close to one another in Euclidean hyperspace.

Difficulty in considering parameters of widely different magnitudes and ranges is overcome by normalization of all parameters to standard variables, Z_{iA}, with zero mean and unit variance.

$$Z_{iA} \equiv \frac{X_{iA} - \bar{X}_i}{S_i}$$

where Z_{iA} = the standardized magnitude of parameter $\underline{i}$ at Station A

X_{iA} = the measured magnitude of parameter $\underline{i}$ at Station A

$\bar{X}_i$ = the mean measured magnitude of parameter $\underline{i}$ (all stations considered)

S_i = the standard deviation of parameter $\underline{i}$ (all stations considered)

In computation, Z_{iA} and Z_{iB} respectively replace X_{iA} and X_{iB} in the expression for Δ_{AB}.

The magnitude of the Euclidean distance, Δ_{AB}, increases for any pair of stations as the number of parameters considered is increased. To eliminate this dependence, an average distance, $\underline{d}_{AB}$, may be calculated (Sokal and Sneath, 1963):

$$d_{AB} \equiv \sqrt{\Delta_{AB}^2/n}$$

where d_{AB} = average distance between Stations A and B

Δ_{AB} = Euclidean distance between Stations A and B

n = number of chemical or chemical/biologic parameters considered.

For standardized, independent, normally-distributed parameters, the expected value of $\underline{d}_{AB}$ converges to $\sqrt{2}$ as $\underline{n}$ approaches infinity, (Sokol and Sneath, 1968).

Biologic Sampling Requirements

Estimation of biologic community structure in natural substrates is confounded by the oft-noted heterogeneity or spatial patchiness of organisms. Sampling of such populations should be conducted so as to provide both an indication of the degree of heterogeneity and some (albeit hypothetical) mean measure of standing crop and structure to allow quantitative comparison of sampling zones or stations.

A biologic community may be considered to possess base population characteristics (density, constituency) governed by gross controlling macrophenonema (i.e. munitions wastes) to which are superposed population variations of lesser magnitude (the apparent random error). The sampling objective is realized when a minimum area or volume is collected such that the error caused by random variations is acceptably small.

In practice, the minimum sampling requirements are generally unknown at the time of collection, unless the investigator has had the benefit of prior studies or preliminary field surveys. If prior information is unavailable, the investigator may choose to bracket the likely requirements and rely upon subsequent detailed laboratory analyses at representative stations to provide that information -- the costs of additional sample collection is usually insignificant relative to the basic expense of a site visit.

One approach to the laboratory determination of minimum sampling requirements is to collect and analyze replicate sets of samples at select stations, each set constituting a unique sampling area or volume. A mean population parameter (diversity, standing crop) may then be plotted against sample area or volume analyzed, bracketed by the calculated standard deviations or confidence limits. Sample size is determined by locating that minimum area or volume where the slope of the plotted data approximates zero and is bracketed by acceptable error limits.

A disadvantage of this procedure is the requirement for collecting and identifying independent replicates of each sample size considered. For an illustrative case, the investigator might collect triplicate sample sets comprised of 1.2, 1.8, 2.3, and 2.9 ft^2 of streambed material if he were studying macrobenthic sampling requirements. These represent a total of 24.6 ft^2 of bottom sediment area and 43 grabs of a 9" x 9½ (60 lb) Ponar dredge or 98 grabs of a 6" x 6" Ekman dredge, both standard benthic samples. Aside from being physically abusive and expending substantial amounts of costly taxonomic identification time, such a program might require disruption of more substrate area than exists in a particular sampling zone.

A modified procedure, applied to this study, utilized the recombination of subsets of the same sample set to estimate mean Shannon-Weaver diversity for any particular sample size. This allowed the determination

of minimum sampling requirements with much greater economy of collection and identification at a sacrifice, however, of precise error limits. For the illustrative case of the prior paragraph, one set of samples totaling 2.9 ft^2 -- 5 hauls of the Ponar or 12 hauls of the petit Ekman dredge could be collected. A plot of mean diversity versus number of dredge hauls (corresponding to varying substrate areas) would be prepared. Mean diversity, $\overline{H}_x$ for x dredge hauls would be calculated as:

$$\overline{H}_x = \sum^{\kappa} H_x^j$$

where $k = c(m,x) = \frac{m!}{x!(m-x)!}$ = the number of combinations of m dredge hauls taken x at a time

m = the total number of dredge hauls collected at a sampling site

H_x^j = the Shannon-Weaver diversity based upon the cumulative taxonomic data of a particular combination, j of x dredge hauls.

Error limits estimated for $\overline{H}x$ are based upon k-1 degrees of freedom. Since k-1 approaches zero as x approaches m, the total number of dredge hauls collected should be somewhat greater than the expected minimum number of dredge hauls required to obtain a reasonably constant estimate of the population diversity.

For macrobenthos both artificial and natural substrate samples were taken. The artificial substrate samplers (Hester-Dendy samplers) were disassembled in the field and preserved on a plate by plate basis. Hence, a replicate consisted of a single plate. For three different sampling sites 15 or 16 plates were counted and tabulated. Utilizing a computer to minimize data processing time, combinations of replicates were pooled utilizing 1, 2, 3, etc. total replicates. Mean pooled Shannon-Weaver values are shown in Figure C-2. In all cases it can be seen that Shannon-Weaver values increased as sample size (total number of replicates pooled) increased up to about seven samples. Addition of more samples to the pool beyond that point had little or no effect on the mean Shannon-Weaver value. Based on these results, seven plates (pooled) were considered to be sufficient to obtain a reasonable estimate of the Shannon-Weaver diversity for the remaining sampling sites.

For macrobenthos in natural substrates the identical procedure was utilized to show that five dredge samples would be sufficient (see Figure C-3).

For diatom populations on artificial substrates (glass slides) this procedure showed five slides to be sufficient (see Figure C-4).

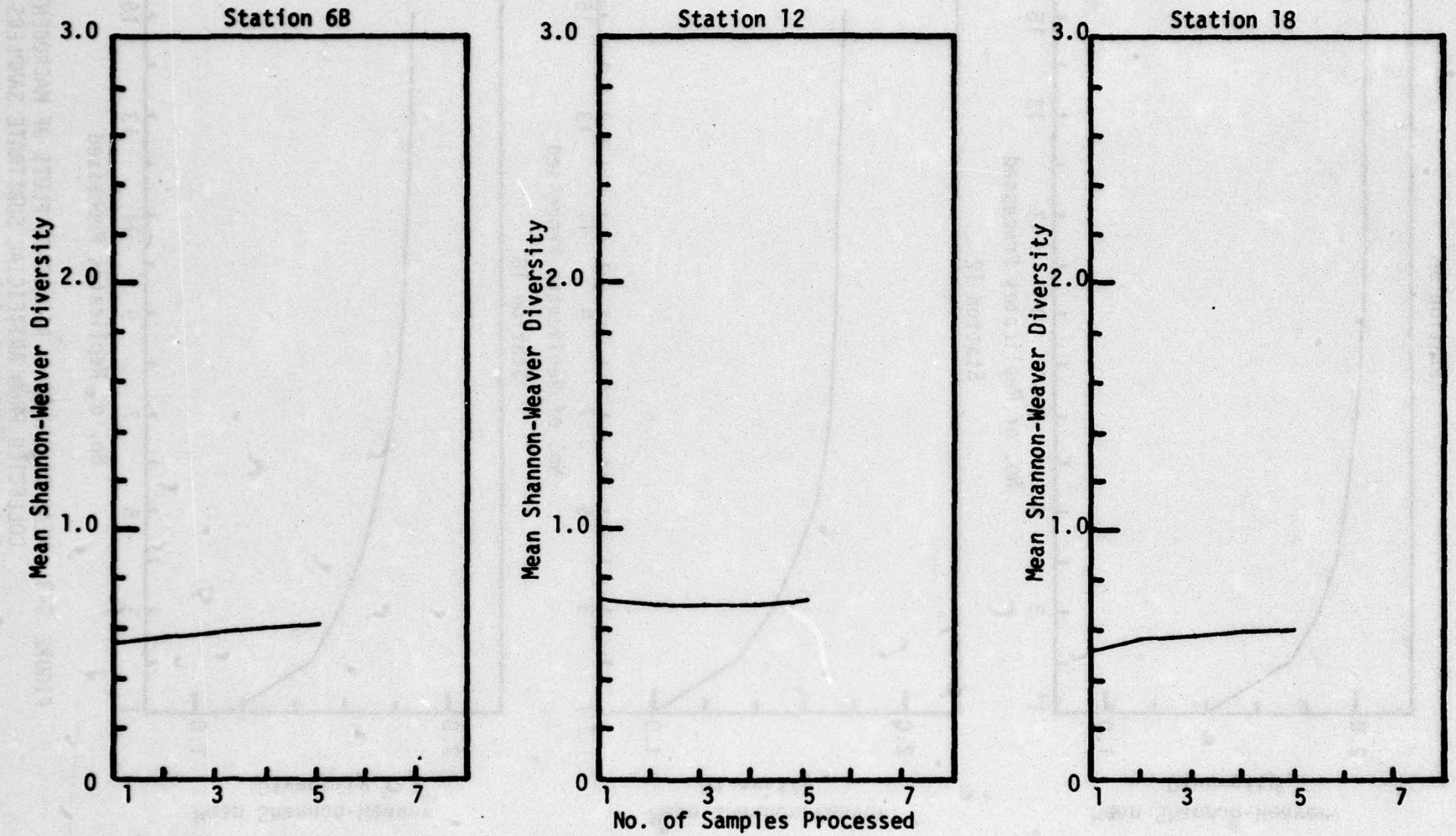


FIGURE C-2. MEAN DIVERSITY - REPLICATE PLOTS OF MACROBENTHOS COLLECTED FROM NATURAL SUBSTRATE DURING THE JUNE STUDY AT HAAP.

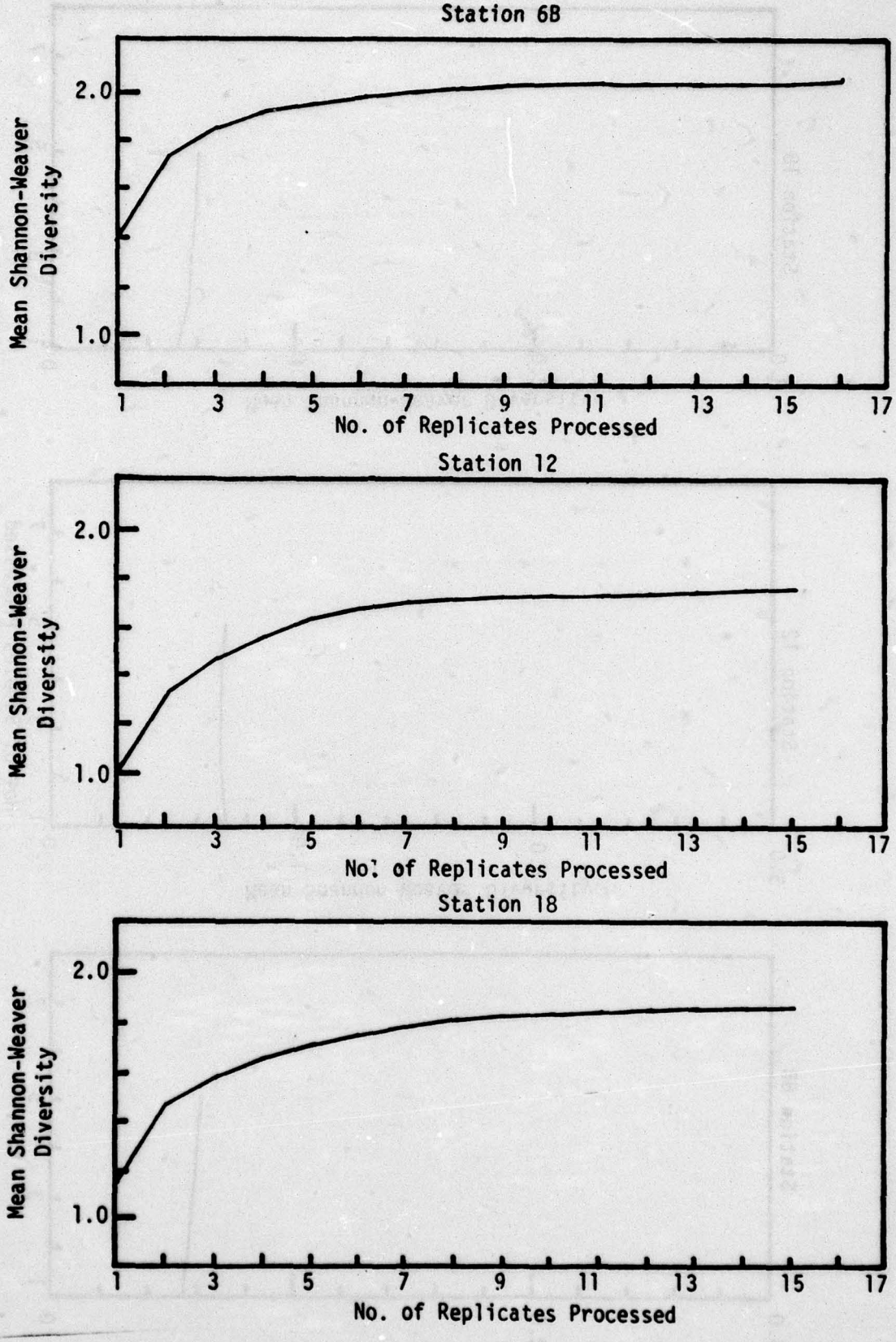


FIGURE C-3. MEAN DIVERSITY - REPLICATE PLOTS OF MACROBENTHOS COLLECTED FROM ARTIFICIAL SUBSTRATE SAMPLERS DURING THE JUNE STUDY AT HAAP.

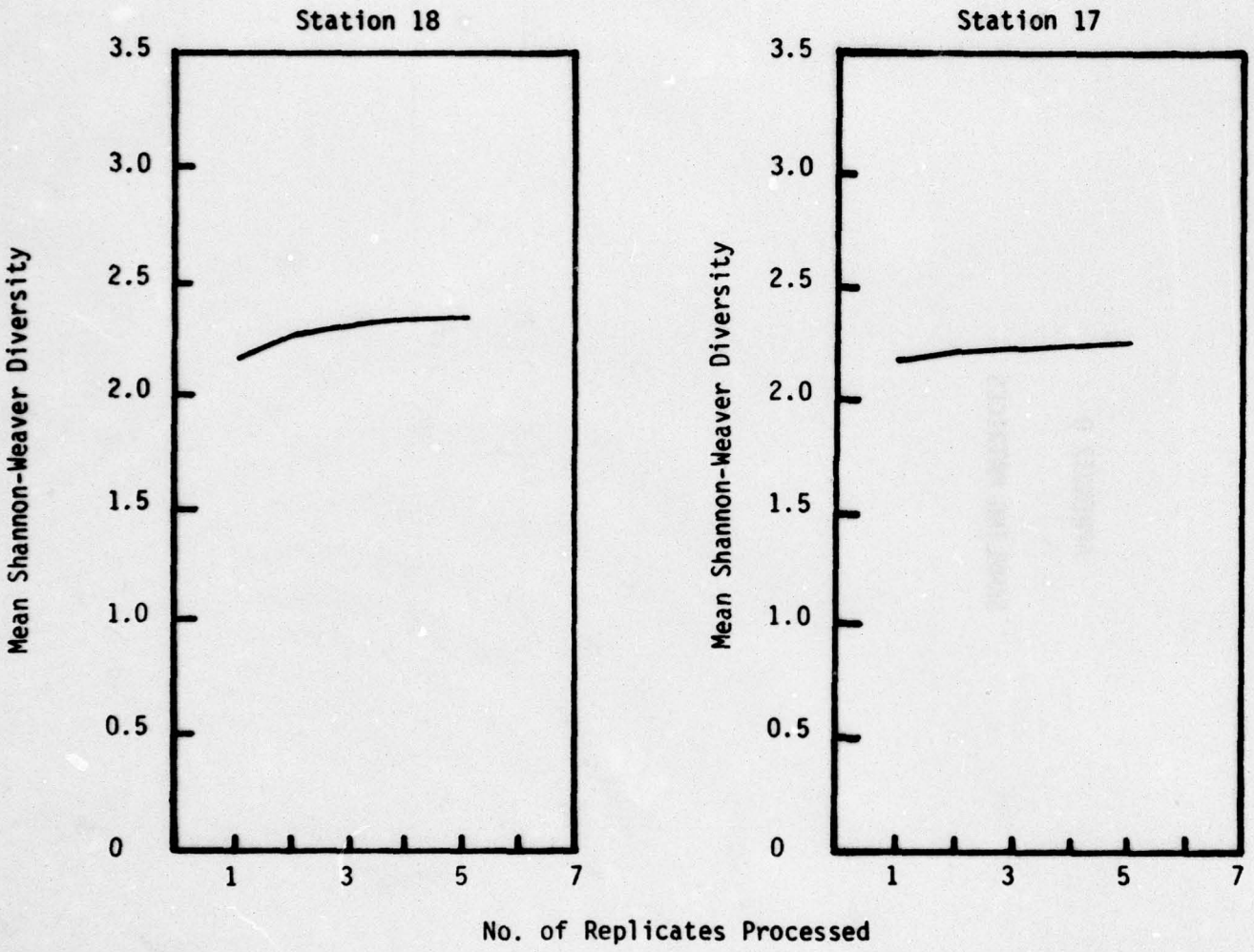


FIGURE C-4. MEAN DIVERSITY - REPLICATE PLOTS OF DIATOMS COLLECTED FROM ARTIFICIAL SUBSTRATE SAMPLES AT THE HAAP SITE AFTER 4 WEEKS INCUBATION
JUNE - JULY 1975

APPENDIX D

SAMPLING MATRICES

LIST OF FIGURES

TABLE D-1

SAMPLING MATRIX FOR HAAP BIOLOGICAL PARAMETERS
JUNE SURVEY

	1	2	3	4-A	4-B	5	6-A	6-B	7-A	7-B	8	9	10	11	12	13	14	15	16	17	18	19	20
PERIPHYTON																							
Artificial Substrate																							
2-Week Incubation																							
Collected	No	No	No	No	Yes	No	Yes	Yes	No	No	No	No	No	No	Yes	No	Yes	No	No	Yes	Yes	No	Yes
Analyzed																							
Organisms	0	0	0	0	3	0	3	2	0	0	0	0	0	0	3	0	3	0	0	3	3	0	3
Biomass	0	0	0	0	5	0	5	5	0	0	0	0	0	0	5	0	5	0	0	5	5	0	5
Chlorophyll	0	0	0	0	2	0	2	2	0	0	0	0	0	0	1	0	0	0	0	2	1	0	2
4-Week Incubation																							
Collected	No	No	No	No	Yes	No	Yes	Yes	No	No	No	No	No	No	Yes	No	Yes	No	No	Yes	Yes	No	Yes
Analyzed																							
Organisms	0	0	0	0	3	0	3	5	0	0	0	0	0	0	3	0	3	0	0	5	5	0	3
Biomass	0	0	0	0	10	0	10	10	0	0	0	0	0	0	10	0	10	0	0	10	8	0	9
Chlorophyll	0	0	0	0	6	0	6	6	0	0	0	0	0	0	5	0	3	0	0	3	1	0	3
Natural Substrate																							
Collected	No	No	No	No	Yes	No	Yes	Yes	No	Yes	Yes	Yes	No	No	Yes	Yes	Yes	No	No	Yes	Yes	No	Yes
Analyzed	No	No	No	No	Yes	No	No	Yes	No	No	No	No	No	No	Yes	No	Yes	No	No	No	Yes	No	No
MACROINVERTEBRATES																							
Artificial Substrate																							
Collected	0	0	0	0	18	0	18	18	0	0	0	0	0	0	18	0	12	0	0	18	18	0	18
Analyzed	0	0	0	0	0	0	7	16	0	0	0	0	0	0	15	0	7	0	0	7	14	0	7
Natural Substrate																							
Collected	0	0	0	0	5	0	5	5	0	5	0*	5	0	0	5	5	5	5	5	5	5	5	5
Analyzed	0	0	0	0	3	0	5	5	0	5	0	0	0	0	5	0	5	0	3	5	5	0	5

* Replicate containing no organisms.

TABLE D-2

SAMPLING MATRIX FOR HAAP BIOLOGICAL PARAMETERS
AUGUST SURVEY

	1	2	3	4-A	4-B	5	6-A	6-B	7-A	7-B	8	9	10	11	12	13	14	15	16	17	18	19	20
PERIPHYTON																							
Artificial Substrate																							
2-Week Incubation																							
Collected	No	No	No	No	Yes	No	No	Yes	No	Yes	Yes	No	No	No	Yes	Yes	No	No	No	No	Yes	No	No
Analyzed																							
Organisms	0	0	0	0	2	0	0	2	0	2	2	0	0	0	2	0	0	0	0	0	2	0	0
Biomass	0	0	0	0	3	0	0	3	0	3	3	0	0	0	3	3	0	0	0	0	0	0	0
Chlorophyll	0	0	0	0	5	0	0	5	0	5	4	0	0	0	5	11	0	0	0	0	0	0	0
4-Week Incubation																							
Collected	No	No	No	No	Yes	No	Yes	Yes	No	Yes	Yes	No	No	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Analyzed																							
Organisms	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Biomass	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chlorophyll	0	0	0	0	7	0	10	7	0	7	7	0	0	0	8	0	0	0	0	0	0	0	0
Natural Substrate																							
Collected	No	No	No	No	Yes	No	Yes	Yes	No	Yes	Yes	No	No	No	Yes	Yes	Yes	No	No	Yes	Yes	No	Yes
Analyzed	No	No	No	No	Yes	No	Yes	Yes	No	Yes	Yes	No	No	No	Yes	Yes	Yes	No	No	Yes	Yes	No	Yes
MACROINVERTEBRATES																							
Artificial Substrate																							
Collected	0	0	0	18	18	0	18	18	0	18	7	0	0	0	18	18	18	0	0	0	18	0	0
Analyzed	0	0	0	0	0	0	7	7	0	7	7	0	0	0	7	7*	7	0	0	0	7	0	0
Natural Substrate																							
Collected	0	0	0	0	5	0	5	5	0	5	9	0	0	0	5	5	5	0	0	5	5	0	5
Analyzed	0	0	0	0	3	0	3	5	0	5	9	0	0	0	5	4	0	0	0	5	4	0	5

* Replicate containing no organisms.

TABLE D-3

SAMPLING MATRIX FOR HAAP CHEMICAL PARAMETERS IN THE WATER COLUMN
JUNE SURVEY

	Station Number																				
	1	2	3	4	5	6A	6B	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Alkalinity	5	5	5	5	5	5	3	5	5	2	5	2	6	5	5	5	5	5	5	5	5
Chemical Oxygen Demand	5	3	5	5	5	5	3	5	5	2	5	2	6	4	5	5	5	5	5	5	5
Ammonia	5	5	5	5	5	5	3	4	-	2	5	2	6	5	5	5	5	5	4	5	5
Total Kjeldahl Nitrogen	5	5	5	5	5	5	3	5	5	2	5	2	6	4	5	5	5	5	5	5	4
Nitrate	5	5	5	5	5	5	3	5	5	2	5	2	6	5	5	5	5	5	5	5	5
Total Organic Carbon	5	5	5	5	5	5	3	5	5	2	5	2	6	5	5	5	5	5	5	5	5
Chloride	5	5	5	5	5	5	3	5	5	2	5	2	6	5	5	5	5	5	5	5	5
Total Hardness	5	5	5	5	5	5	3	5	5	2	5	2	6	5	5	5	5	5	5	5	5
Total Solids	5	5	5	5	5	5	3	5	5	2	5	2	6	5	5	5	5	5	5	5	5
Suspended Solids	5	5	5	5	5	5	3	5	5	2	5	2	6	5	5	5	5	5	5	5	5
Total Dissolved Solids	5	5	5	5	5	5	3	5	5	2	5	2	6	5	5	5	5	5	5	5	5
Sulfate	1	1	1	1	2	2	1	2	2	1	2	1	2	2	2	3	3	3	3	3	3
Nitrite	4	4	4	4	4	4	2	4	4	2	4	2	5	4	4	4	4	4	4	4	4
Munitions	5	5	5	5	5	5	3	5	5	2	5	2	6	5	5	5	5	5	5	5	5
Total Phosphorus	5	5	5	5	5	5	3	5	5	2	5	2	6	5	5	5	5	5	5	5	5

TABLE D-4

SAMPLING MATRIX FOR HAAP CHEMICAL PARAMETERS IN THE WATER COLUMN
AUGUST SURVEY

Parameter	Station Number																					
	1	2	3	4	5	6A	6B	7	7B	8	9	10	11	12	13	14	15	16	17	18	19	20
Alkalinity	-	-	5	7	5	5	5	5	5	5	-	5	-	5	5	5	-	5	5	5	-	5
Chemical Oxygen Demand	-	-	5	7	5	5	5	5	5	5	-	5	-	5	5	5	-	5	5	5	-	5
Ammonia	-	-	4	7	5	5	5	4	5	2	-	4	-	5	5	4	-	5	5	5	-	5
Total Kjeldahl Nitrogen	-	-	5	7	5	5	5	5	5	5	-	5	-	5	5	5	-	5	5	5	-	5
Nitrate	-	-	5	7	5	5	5	5	5	5	-	5	-	5	5	5	-	5	5	5	-	5
Nitrite	-	-	5	7	5	5	5	5	5	5	-	5	-	5	5	5	-	5	5	5	-	5
Total Phosphorus	-	-	5	7	5	5	5	5	5	5	-	5	-	5	5	5	-	5	5	5	-	5
Total Organic Carbon	-	-	4	5	4	4	4	4	4	4	-	4	-	4	4	4	-	4	4	4	-	4
Chlorides	-	-	3	4	3	3	3	3	2	2	-	3	-	3	3	3	-	3	3	3	-	3
Total Hardness	-	-	3	3	3	3	3	3	2	2	-	3	-	3	3	3	-	3	3	3	-	3
Sulfate	-	-	2	2	2	2	2	2	2	1	-	2	-	2	2	2	-	2	2	2	-	2
Total Solids	-	-	5	7	5	4	5	5	5	5	-	5	-	5	5	5	-	4	5	4	-	5
Suspended Solids	-	-	5	7	5	4	5	5	5	5	-	5	-	5	5	5	-	4	5	4	-	5
Total Dissolved Solids	-	-	5	7	5	4	5	5	5	5	-	5	-	5	5	5	-	4	5	4	-	5
Munitions	1	-	5	7	5	5	5	5	5	5	-	5	-	5	5	5	-	5	5	5	-	5

TABLE D-5

SAMPLING MATRIX FOR HAAP CHEMICAL PARAMETERS IN THE SEDIMENTS
JUNE SURVEY

	Station Number																					
	1	2	3	4	4B	6A	6B	7	7B	8	8B	9	10	12	13	14	15	16	17	18	19	20
Total Kjeldahl Nitrogen	1	1	1	1	0	2	2	1	0	1	0	1	1	2	1	2	2	1	1	1	1	2
Nitrate Nitrogen	1	1	1	1	0	2	2	1	0	1	0	1	1	2	1	2	2	1	1	1	1	2
Nitrite Nitrogen	1	1	1	1	0	1	1	1	0	1	0	1	1	1	1	1	1	1	1	1	1	1
Total Phosphorus	1	1	1	1	0	1	1	1	0	1	0	1	1	1	1	1	1	1	1	1	1	1
Chemical Oxygen Demand	1	1	1	1	0	1	1	1	0	1	0	1	1	1	1	1	1	1	1	1	1	1
Total Volatile Solids	1	1	1	1	0	3	2	1	0	1	0	1	1	3	1	2	2	1	1	1	1	2
Total Solids	1	1	1	1	0	3	2	1	0	1	0	1	1	3	1	2	2	1	1	1	1	2
Munitions	0	0	0	0	0	3	1	0	0	0	0	0	0	2	0	1	1	0	0	0	0	1
Mercury	0	1	1	1	0	1	1	1	0	2	0	0	2	1	1	1	0	0	0	0	1	1
Cadmium	1	1	2	2	0	1	1	2	0	1	0	1	1	2	1	1	1	1	1	1	1	1
Chromium	0	0	1	1	0	0	1	1	0	1	0	0	0	3	0	0	0	0	0	0	0	0
Copper	1	1	2	2	0	1	2	2	0	1	0	1	1	3	1	1	1	1	1	1	1	2
Iron	1	1	2	2	0	1	1	2	0	1	0	1	1	2	1	1	1	1	1	1	1	1
Lead	1	1	2	2	0	1	2	2	0	1	0	1	1	3	1	1	1	1	1	1	1	2
Nickel	1	1	2	2	0	1	1	2	0	1	0	1	2	2	1	1	1	1	1	1	1	1
Zinc	1	1	2	2	0	1	2	2	0	1	0	1	1	3	1	1	1	1	1	1	1	2
Manganese	1	1	2	2	0	1	1	2	0	1	0	1	1	2	1	1	1	1	1	1	1	1

TABLE D-6

SAMPLING MATRIX FOR HAAP CHEMICAL PARAMETERS IN THE SEDIMENTS
AUGUST SURVEY

	Station Number																					
	1	2	3	4	4B	6A	6B	7	7B	8	8B	9	10	12	13	14	15	16	17	18	19	20
Total Kjeldahl Nitrogen	0	0	0	0	1	1	1	0	1	0	1	0	0	2	2	2	0	0	1	2	0	2
Nitrate Nitrogen	0	0	0	0	1	1	1	0	1	0	1	0	0	2	2	2	0	0	2	2	0	2
Nitrite Nitrogen	0	0	0	0	1	1	1	0	1	0	1	0	0	1	1	1	0	0	1	1	0	1
Total Phosphorus	0	0	0	0	1	1	1	0	1	0	1	0	0	1	1	1	0	0	1	1	0	1
Chemical Oxygen Demand	0	0	0	0	1	1	1	0	1	0	1	0	0	1	1	1	0	0	1	1	0	1
Total Volatile Solids	0	0	0	0	1	2	2	0	2	0	2	0	0	2	2	2	0	0	2	2	0	2
Total Solids	0	0	0	0	1	2	2	0	2	0	2	0	0	2	2	2	0	0	2	2	0	2
Munitions	0	0	0	0	0	1	1	0	1	0	1	0	0	0	1	1	0	0	0	1	0	1
Mercury	0	0	0	0	1	0	1	0	1	0	1	0	0	1	0	1	0	0	1	1	0	1
Cadmium	0	0	0	0	1	0	1	0	0	0	0	0	0	1	0	1	0	0	1	1	0	1
Chromium	0	0	0	0	1	1	2	0	1	0	1	0	0	2	1	1	0	0	2	1	0	1
Copper	0	0	0	0	1	1	2	0	1	0	1	0	0	2	1	1	0	0	2	1	0	1
Iron	0	0	0	0	1	0	1	0	0	0	0	0	0	1	0	1	0	0	1	1	0	1
Lead	0	0	0	0	1	1	2	0	1	0	1	0	0	2	1	1	0	0	2	1	0	1
Nickel	0	0	0	0	1	0	1	0	0	0	0	0	0	1	0	1	0	0	1	1	0	1
Zinc	0	0	0	0	1	1	2	0	1	0	1	0	0	2	1	1	0	0	2	1	0	1
Manganese	0	0	0	0	1	0	1	0	0	0	0	0	0	1	0	1	0	0	1	1	0	1

TABLE D-7

SAMPLING MATRIX FOR HAAP METALS IN THE WATER COLUMN JUNE SURVEY

	1	2	3	4	5	6A	6B	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Mercury	5	4	5	5	5	3	3	5	4	2	5	2	6	5	5	5	4	5	5	4	4
Cadmium	-	-	1	1	-	-	-	1	1	-	1	-	1	-	-	-	-	-	-	-	-
Chromium	-	-	1	1	-	-	-	1	1	-	1	-	1	-	-	-	-	-	-	-	1
Copper	-	-	1	1	-	-	-	1	1	-	1	-	1	-	-	-	-	-	-	-	1
Iron	-	-	1	1	-	-	3	6	6	-	6	-	-	-	-	-	-	-	-	-	4
Lead	-	-	1	1	-	-	3	5	5	-	5	-	-	-	-	-	-	-	-	-	4
Nickel	-	-	1	1	-	-	-	1	1	-	1	-	1	-	-	-	-	-	-	-	-
Zinc	-	-	1	1	-	-	-	1	1	-	1	-	1	-	-	-	-	-	-	-	-

TABLE D-8

SAMPLING MATRIX FOR HAAP METALS IN THE WATER COLUMN AUGUST SURVEY

	Station Number																				
	1	2	3	4	5	6A	6B	7	7B	8	9	10	11	12	13	14	15	16	17	18	19	20
Mercury	-	-	5	6	5	2	2	2	-	3	-	3	-	5	-	-	-	-	-	-	-	3
Chromium	-	-	2	3	2	2	2	2	2	1	-	2	-	2	2	2	-	2	2	2	-	2
Copper	-	-	2	3	2	2	2	2	2	1	-	2	-	2	2	2	-	2	2	2	-	2
Iron	-	-	2	3	2	2	2	2	2	1	-	2	-	2	2	2	-	2	2	2	-	2
Lead	-	-	2	5	2	2	2	2	2	1	-	2	-	2	2	2	-	2	2	2	-	5
Nickel	-	-	2	5	2	2	2	2	2	1	-	2	-	2	2	2	-	2	2	2	-	5
Zinc	-	-	2	5	2	2	2	2	2	1	-	2	-	2	2	2	-	2	2	2	-	5

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